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# Static Analysis of Lyee Requirements for Legacy System Software

Hamido Fujita and Mohameed Mejri

**Abstract—** *Software development has been suffering, for many decades, from the lack of simple and powerful methodologies and tools. Despite the tremendous advances in this research field, the crisis has still not been overcome and the proposed remedies are far from resolving the problems of software development and maintenance. Lately, a new and very promising methodology, called Lyee, has been proposed. It aims to automatically generate programs from simple user requirements.*

*The purpose of this paper is, on the one hand, to provide a short and technical introduction to the Lyee software development methodology, and on the other hand, to show how some classical static analysis techniques (execution time and memory space optimization, typing, slicing, etc.) can considerably improve many aspects of this new methodology. This paper contributes on introducing new techniques for software system design, for legacy systems.*

**Index Terms—** *Software development, Lyee methodology, static analysis, dynamic analysis*

## 1. INTRODUCTION

SOFTWARE development and maintenance have become activities of major importance to our economy. As software comes into widespread use, this activity involves a large industry. Hundreds of billions of dollars are spent every year in order to develop and maintain software.

Today, competition between actors in the software development field is fiercer than ever. To remain in the race, these actors (companies) must keep productivity at its peak and costs low. They must also deliver products (software) at high quality and deliver them on time. However, an important question is whether the available tools and methodologies for software development suit company needs.

The work reported here contributed to research study on building legacy systems based on Lyee framework, (<http://www.lyee-project.soft.iwate-pu.ac.jp>).

More detailed version of this paper is available at <http://www.lyee-project.soft.iwate-pu.ac.jp/IPSI>.

Basically, the goal of software development research is to find ways how to build better software easily and quickly. A large variety of methodologies and techniques have been proposed and elaborated on, over the last 10 years, to improve one or more steps in the software development life cycle. Despite their considerable contributions, they have had difficulty to finding their way into widespread use. In fact, almost all of them fail to produce clearly understood and modifiable systems and their use is still considered to be an activity accessible only to specialists with a large array of competencies, skills, and knowledge. This, in turn, leads to highly paid personal, high maintenance costs, and extensive checks needing to be performed on the software.

**Lyee** [1-4] (governmental methodology for software providence) is specific new and promising methodology. Intended to deal efficiently with a wide range of software problems related to different fields, Lyee allows the development of software by

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simply defining its requirements. More precisely, a developer has only to provide words, calculation formulae, calculation conditions (preconditions) and layout of screens and printouts, and then leaves in the hands of the computer all subsequent troublesome programming process (e.g., control logic aspects). Despite its recency, the results of the use of Lyee have shown tremendous potential. In fact, compared to conventional methodologies, development time, maintenance time and documentation volume can be considerably reduced by using Lyee (as much as 70 to 80%)

2. Up to now, a primitive supporting tool called **LyeeAII2** has been available to developers allowing the automatic generation of code from requirements. Nevertheless, as with any new methodology, further research is needed on Lyee to investigate its efficiency, to discover and eliminate its drawbacks, and to improve its good qualities.

In this paper, we show how classical static analysis techniques can considerably contribute the analysis of Lyee requirements (a set of words within their definitions, their calculation conditions and their attributes) in order to help their users understand them, discover their inconsistencies and incomplete or erroneous parts, and generate codes of better qualities (consuming less memory and execution time). Basically, the static analysis techniques we investigate are:

- ? Optimization techniques (constant propagation, communication sub expression detection, etc.) to generate better Lyee programs.
- ? Slicing techniques to abstract requirements to their relevant part needed for some analysis.
- ? Typing techniques to automatically generate types and to discover typing errors.

The remainder of this paper is organized as follows. In Section 2, we give a short and technical introduction to the Lyee methodology. Section 3 shows how static analysis techniques can contribute to the

enhancement of this methodology. Section 4 introduces LyeeAnalyzer, a prototype that we have developed to implement some

static analysis techniques. Finally, Section 5 provides concluding remarks on this work, and discusses future research.

## 2. THE LYEE METHODOLOGY

Most people who have been seriously engaged in the study and development of software systems agree that one of the most problematic tasks in this process is that of understanding requirements and correctly transforming them. To solve this problem, the Lyee methodology proposes a simple method for to generating programs from requirements.

With the Lyee methodology, requirements are given as a set of statements containing words together with their definitions, their calculation conditions and their attributes (input/output, type, etc.). A word is an atomic element and its definition and calculation conditions show its interaction with the other words.

Although the philosophic principles behind the Lyee methodology are interesting, in this section we focus only on some practical ideas useful to understand how to write software using this methodology and how to understand the code that is automatically generated from Lyee requirements.

### 2.1 Lyee requirements

Within the Lyee methodology, requirements are given in a declarative way as a set of *statements* containing words together with their definitions, their calculation conditions and their attributes (input/output, types, security attributes, etc.). For the sake of simplicity, throughout this paper, we consider each statement to contain the following information:

- ? Word: An identifier of a word.
- ? Definition: An expression defining a word.

We suppose, for the sake of simplicity, that an expression can be one of the following: (where *\_* is the empty expression)

Exp := val | id \_ (Exp) | op Exp | Exp op Exp

val:= num | num.num | bool

num:= 0 | 1.. |9| num num

bool:= true| false

id:=a | ....|z| A | .... |Z| id num|

id id

Op :=+| -|\*|or |and |< |<= |=

|<> |> |>= |not

? Condition: the calculation condition of the word; this is an expression *Exp* that must be boolean. If there is no condition (the condition is always true) we leave this field empty.

? IO: specifies whether the defined word is an input, output or intermediate word (neither an input nor an output). If the word is an input, this field can take the value IF (input from file) or IS (input from screen). Similarly, if the word is an output, then this field can take the value OF or OS. However, if the word is intermediate, we leave this field empty.

? Type: specifies the type of the word. It can take on one of values *int*, *float* or *bool*.

? Security: associates a security level with the defined word. It takes on one of the following values *public* or *secret*.

Notice that the fields "Type" and "Security" can be empty if the defined word is not an input. Notice also, that other types and other security levels can be easily incorporated to support others Lyee requirements.

In the rest of this paper, if *s* is a statement, then we use:

?  $s_w$

to denote the statement defining a word *w*.

? Definition (*s*)

to denote the field "Word" of *s*.

? Condition(*s*)

to denote the field "Condition" of *s*.

? IO(*s*)

to denote the field "IO" of *s*.

? Type(*s*)

to denote the field "Type" of *s*.

? Security(*s*)

to denote the field "Security" of *s*.

Table 1 below gives an example of Lyee requirements.

Word	Definit- ion	Condit- ion	IO	Typ e	Securi- ty
a	b+c	b*e>2	OF	int	secret
c			IS	float	public
b	2*c+5	c>0		float	public
e				float	public

Table 1: Example of Lyee requirements.

The requirements given in Table 1, correspond intuitively, in a traditional programming language, to the code given in Table 2.

Stat e- ment	Code
$s_a$	If b*e>2 then a:=b+c; output(a); endif
$s_c$	Input(c);
$s_b$	If c>2 then b:=2*c+5; output(b); endif
$s_e$	Input(e);

Table 2: Statement code

Within the Lyee methodology, the user does not need to specify the order (control logic) in which these definitions will be executed. As shown in Table 2, despite the fact that the definition of word *a* uses word *b*, statement  $s_b$  is listed after the statement  $s_a$ . As explained in the sequel, from these requirements, and independent of the order of statements, Lyee is able to generate code that computes all the defined words.

This simple idea has, as shown in [1-4], multiple beneficial consequences on the different steps of software development. In fact it allows us to begin developing of software even with incomplete requirements.

Moreover, the user need not deal with control logic as with more classical methodologies. The control logic part of the software will be, within the Lyee methodology, automatically generated reducing consequent programming errors and time.

Flexibility is also a major benefit of the Lyee methodology since the maintenance task can be reduced to a simple modification of requirements (add, remove and/or modify words' definitions).

## 2.2 Code Generation

From the requirements in Table 1, we can automatically generate a program that computes the values of *a* and *b* and outputs them. This program will simply repeat the execution of these instructions until a fixed point is reached, i.e., any other iteration will not change the value of any word as shown in Fig. 1

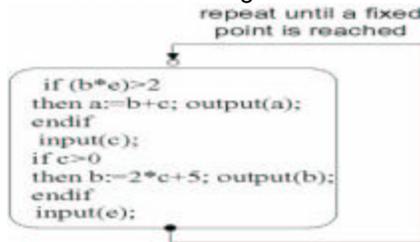


Fig. 1, Requirement Execution.

Let's be more precise about the structure and the content of the program that will be automatically generated by Lye from requirements. Within the Lye methodology, the execution of a set of statements, such as the ones given in Table 1, is accomplished in a particular manner. In fact, Lye distributes the code associated with statements over three spaces, called *Pallets* (*W02*, *W03* and *W04*) in the Lye terminology, as shown in Fig.2.

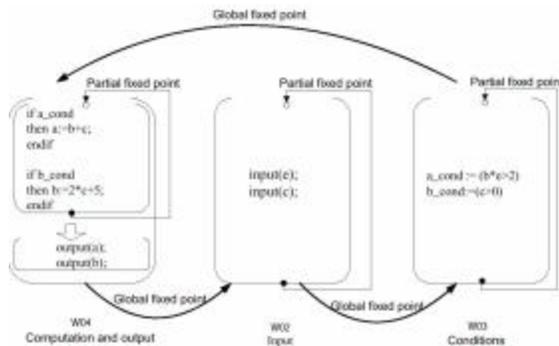


Fig.2. Lye Pallets

Pallet *W02* deals with the input words. Pallet *W03* computes the calculation conditions of the words and saves the results in boolean variables. For instance, the condition " $b \cdot e > 2$ " used within the definition of the word "*a*" is calculated in *W03* and the true/false result is saved in another variable "*a\_cond*". Finally, pallet *W04* deals with the calculation of the words according to their

definition given within the requirements. It also, outputs the values of the computed words.

Starting from pallet *W04*, a Lye program tries to compute the values of all the defined words until a fixed point is reached. Once there is no evolution in *W04* concerning the computation of the word values, control is given to pallet *W02*. In its turn, this second pallet tries repeatedly to input values of words until a fixed point is reached (no others inputs are available) and then transfer the control to pallet *W03*. Finally, and similar to pallet *W04*, pallet *W03* tries to compute the calculation conditions of the words according to the requirements until a fixed point is reached. As shown in Fig.3, this whole process (*W04* ? *W03* ? *W02*) will repeat until a situation of overall stability is reached and the three pallet linked together are called Scenario Function.

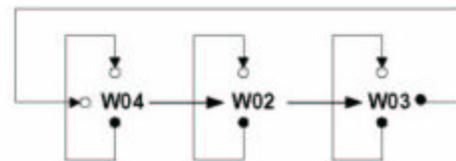


Fig.3. Scenario Function

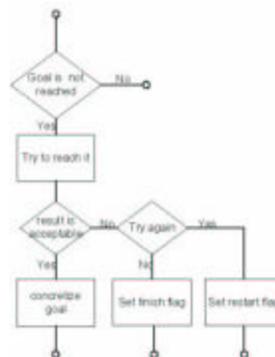


Fig.4. Predicate Vector

In addition, Lye has established a simple program with a fixed structure (called a Predicate Vector in the Lye terminology) that makes the structure of generated code uniform and independent of the requirement content. The global program will be simple calls of predicate vectors. The structure of a predicate vector is as shown in Fig.4.

The goal of a predicate vector changes from one pallet to another. For instance, in the pallet W04, the first goal is to give a value to a word according to its definition. For the example shown in Fig. 2, the predicate vectors associated with the calculation of the word "a" and the word "b" are as shown in Fig.5.

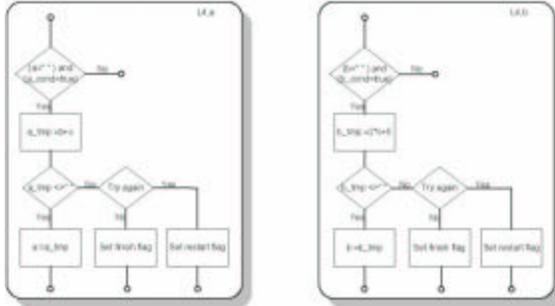


Fig. 5. The Predicate Vectors of L4, a and L4, b.

Finally, in pallet W03, the goal of the predicate vectors is to compute preconditions specified within requirements as shown in Fig. 6.

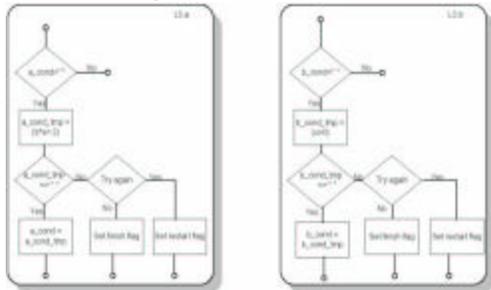


Fig.6. The predicate Vectors of L3, a and L3,b.

Finally, the Lye program associated with the requirements given in Table 1 is as shown in Table 3.

pallet	Program	Comments
W04	Call S4 Do Call L4_a Call L4_b While a fixed point is not reached Call 04 Call R4	Initialize memory  Calculate a Calculate b  Output the result Go to W02
W02	Do Call L2_e Call L2_c While a fixed point is not reached Call I2	

	Call R2	
W03	Do Call L3_a Call L3_b While a fixed point is not reached Call R3	Calculate a_cond Calculate b_cond  Go to W04

Table: 3 Lye Generated Program

### 2.3 Process Route Diagrams

The Scenario Function presented in the previous section can be a complete program for a simple case of given requirements, particularly when all the input and output words belong to the same screen and there is no use of any database. However, if we need to input and output words that belong to databases or to different screens interconnected together, then the situation will be more complicated. For the sake of simplicity, we deal, in the sequel, only with the case when we have many screens. Suppose for instance that we have three interconnected screens, as shown in Fig.7, allowing a user to navigate from one to another.

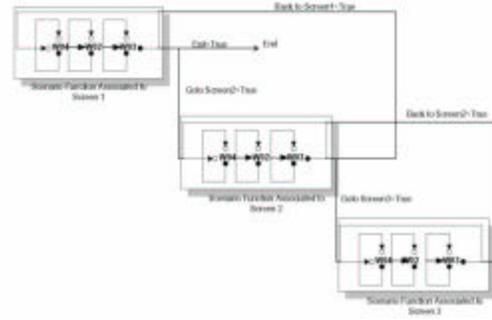


Fig. 7. Screen Interactions

In fact, some screens may not be visited for a given execution of the program and then the computation of the value of their words will be lost. For that reason, Lye associates with each screen its own scenario function that will be executed only if this screen is visited. The scenario functions associated with screens are connected together showing the move from one of them to another. In the Lye terminology, many scenario functions connected together make up a Process Route Diagram as shown in Fig. 8.

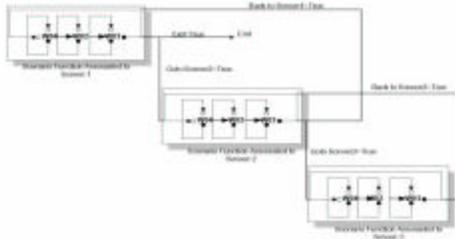


Fig. 8. Processes Route Diagram

To summarize, according to the Lyee methodology, a program usually contains several PRDs. Each of these is a set of interconnected scenario functions and each scenario function contains three interconnected pallets *W02*, *W03* and *W04*.

#### 2.4 Drawback of the Methodology

In spite of the Lyee methodology is simplicity and its several positive impacts on all the steps of the software development cycle, it suffers from a major drawback, namely, the size of the generated code. In fact, to each word given within requirements, it attributes several memory areas. For more details about the exact amount of memory consumed by each word, the reader can refer to [2,3].

The remainder of this paper shows how static analysis techniques can help produce Lyee programs that run faster and consume less memory space, as well providing other beneficial qualities.

### 3. STATIC ANALYSIS OF LYEE REQUIREMENTS

Software static analysis [5,6] generally means the examination of the code of a program without running it. Experience has shown that many quality attributes of specifications and codes can be controlled and improved by static analysis techniques. In particular, static analysis techniques can make programs run faster and use less memory, and they can help locate faults. Applied on requirements, static analysis finds logic errors and omissions before the code is generated and consequently allows the user to save precious development and testing time. The purpose of this section is to pinpoint some static analysis techniques that could improve the qualities of Lyee requirements and code generated from those requirements.

## 4. LYEEANALYZER

The LyeeAnalyzer prototype was developed to demonstrate the static analysis techniques presented in this paper.

### 4.1 Inputs and Outputs

The LyeeAnalyzer takes as input Lyee requirements and can produce as output slices and ordered requirements suitable for the generation of optimized code by the LyeeAll2 tool. In addition, it can perform other requirement optimizations, such as constant propagation, and verifications such as type safety. The interface of the prototype is as shown in Figure.9. The buttons in the top part of the window propose to access to the different static analysis techniques implemented in the tool; the inputs defined on the left frame, and the out in the right hand frame.

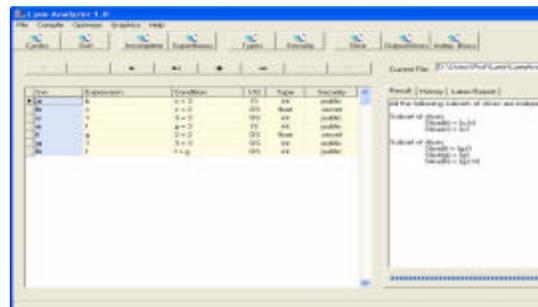


Fig.9. LyeeAnalyzer main interface

### 4.2 LyeeAnalyzer Architecture

The basic components of this prototype are the following:

? **Lexical and Syntactic Analyzers:** These components take as input Lyee requirements and give as output a syntactic tree commonly called an intermediate representation. This new representation of requirements is the starting point of all the static analysis techniques that we perform. Furthermore, when parsing the Lyee requirements, lexical or syntactic errors can be detected and communicated to the user.

? **Semantics Analyzer:** This component allows the discovery of type errors, security violations, incomplete statements, dead statements, cyclic statements and superfluous statements. It also allows us to generate the missing types, i.e., it generates the types of all output and intermediate words.

? Flow-Based Analyzer: Starting from the intermediate representation generated by the previous components, the flow-based analysis component generates all information related to the circulation of control and data flow from one requirement point to another. The results of these analyses consist of two graphs:

?Control Flow Graph: Each node of this graph contains a single statement of requirements and an edge between two nodes represents direct flow of control between them.

? Data-Flow Graph: Each node of this graph contains a single statement of requirements and an edge between two nodes represents a data flow (Def/Use information) between them.

?Optimizer: Amongst others, this component implements the constant propagation techniques and generates an ordered and simplified sequence of statements suitable for the LyeeAll2 tool to produce a program that runs faster and consumes less memory.

? Slicer: This component takes as input flow information (such as the Def/Use information associated with each word) generated by the Flow-Based Analysis component and one or many slicing criteria and gives as output slices that correspond to these criteria. Within the classical programming language, a slicing criterion is generally considered a pair  $C=(s,V)$ , where  $s$  is a statement and  $V$  a set of variables. Slicing a program according to this criterion means the generation of all statements relevant to the computation of the variables in  $V$  given before the statement  $s$ . The LyeeAnalyzer uses the VCG (Visualization of Compiler Graphs)[13] tool to display the various involved results (independent bloc, optimized code, etc.).

The LyeeAnalyzer prototype is intended to achieve at least the following goals:

? Help the LyeeAll2 tool to generate efficient programs.

? Help the user to understand and maintain Lyee requirements, especially for those containing a large number of statements: Among others, the slicing technique is potentially suitable for this goal.

? Help the user debug requirements: Finding incomplete or inconsistent requirements.

? Automatic parallelization: Identifies independent slices that could be computed in parallel.

? Automatic generation of types: Given the types of the input words, this tool generates the types of output and intermediate words.

## 5. CONCLUSION AND FUTURE WORK

We have reported in this paper the use of static analysis techniques on the Lyee requirements and their impacts. First, we have shown how classical optimization techniques such as constant propagation and common subexpression detection can be used to improve the execution time of the Lyee programs. We have also shown how to discover errors in requirements (dead definition, cyclic definition, incomplete or superfluous definitions). Second, we have shown how slicing techniques can potentially improve the understanding and the maintenance of Lyee systems. Also, we have shown how to find independent parts of Lyee systems that can be executed in parallel using slicing techniques. Third, we have proposed a type system allowing both the detection of typing errors and the automatic generation of types of the intermediate and output words. Fourth, we have shown how the Lyee methodology is suitable for some extensions such as security aspects. Some of the presented static analysis techniques are now implemented in a prototype called LyeeAnalyzer. As future work, we want to investigate other static and dynamic analysis techniques to improve other aspects of the Lyee methodology.

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He is also the general Chair of the SOMET conferences series, <http://www.lyee-project.soft.iwate-pu.ac.jp/en/conference/index.html>.

# A Distributed Multimedia Information System for Cultural Heritage Identity preservation

Aldo Aiello, Mario Mango Furnari, and Antonio Massarotti

**Abstract—** *In this paper we describe the architecture of a Distributed Content Management System developed to organize the cultural information in such a way that the cultural identity of a community could be easily communicated. One of the major problems investigated was how the information integration could simplify the “relevant” information looking for process. Here, the notion of contents community was developed, together with a set of tools, in order to organize the document information space. Each content provider publishes a set of ontologies, to collect metadata information, organized and published through the Contents Community Authority. These methodologies were deployed setting up a prototype that connects about 20 museums in the city of Naples (Italy).*

**Index Terms—***Multimedia Information System, Distributed Information Systems, Cultural Heritage Content Management*

## I. INTRODUCTION

In the last decade, cultural heritage has received an increased attention and has been recognized as an important aspect for social groups in order to preserve human being community identity. Many efforts have been devoted to cope with the Cultural Heritage preservation, promotion, and economic exploitation problems. To a greater degree, technology is solving one of

the largest problematic issues concerning cultural heritage assets: their *nondestructive public access*. Never before, there have been greater opportunities to explore and discover in great details these marvels of earth and of humankind without the fear of irreparable damage. Cultural heritage preservation technology is now establishing new ways to explore complex problems and to provide solid pathways to real solutions.

Many information systems and international initiatives were started up to collect and manage information about *cultural heritage artifacts*. Furthermore, to gain a wide audience and to promote a standardization process, many efforts are on going, for example [2], [3], [4], and [8].

With the wide acceptance of the *World Wide Web* (WWW) metaphor, most systems were transformed to replace the notion of record with that of *document* as elementary information entity around which to design the information systems. On designing a Multimedia Information System to promote cultural community identity this change over is becoming more evident and it is stressing out the browsing and portal approaches limitations. In fact, the cultural identity of a community is only partially represented by the cultural heritage artifacts organized in Museums. We think that a more comprehensive representation is better given by showing up all the relationships that there exist between museum artifacts and social-urban tissue.

The objectives of Cultural Heritage Information Systems should be established as a federated network of culture related information providers, where all contents should be available to mass public,

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professionals and market operators through cooperating information systems. For such systems, the cooperation process should be focused on the re-organization and unification process of the existing relevant information resources. The cooperation would account for heterogeneous, dynamically changing and autonomous services to be combined into a single logical service. One promising approach to be exploited on pursuing the previous goals is given by the Semantic Web Initiative [1].

In this paper, we address the problem of making existing distributed document collection repositories mutually interoperable at semantic level. We argue that emerging semantic web technologies offer a promising approach to facilitate semantic information retrieval based on heterogeneous document repositories distributed on the web. Here, we also describe the authors' efforts in designing and implementing a test bed to verify on the field some of the emerging web technologies to be deployed in order to experiment the semantic web approach, on the cultural heritage promotion arena.

The rest of the paper is organized as follows: In Section II the architecture and the implementation of the proposed Distributed Multimedia Document Information System are given. In Section III the implemented test bed is described. In Section IV, the advantages of the proposed architecture are summarized by comparing them with other efforts.

## II. THE ARCHITECTURE OF A DISTRIBUTED CONTENTS MANAGEMENT SYSTEM

As distributed contents management system design criteria we chose the WWW paradigm: where *document* plays the role of elementary information and it is the basic information systems building block. Furthermore, we adopted the multi-tiers web architecture, with the application server playing the central role of business logic driver. In other words, we have an http server taking care of all the interactions with the external world and being also in charge to asynchronously send messages to the application server. The application server takes care of the *request* messages, interprets them creating chains of actions

that it dispatches to corresponding specialized components. Once an invoked component has terminated the computations, it sends back the responses to the application server that assembles them into *response* messages and sends them back, through the http server, to the clients located into the external world. The main identified components belonging to the *application layer* are:

- *Document Repository System (DRS)*. The DRS stores and organizes the documents together with the associated metadata.
- *Document Access System (DAS)*. The DAS creates friendly and flexible user interfaces to discover and access the contents.
- *Contents Authority Management System (CAS)*. The CAS stores and manages the ontologies used by each participating node to facilitate the DRS semantic interoperability.

All these systems communicate among them exchanging XML encoded messages over http, according to well-defined protocols that represent the XML communication bus core. The components of each multimedia documents repository node are implemented as a collection of servers coordinated by an application server and published on Internet by an http server.

From the functional point of view, the distributed system is built as a collection of multimedia documents repository nodes, glued all together by a communication infrastructure that takes care not only for the communication channels but even for the necessary services/components for nodes registration, for XML messages routing, and so on. Since, in a distributed setting, the network infrastructure and services must be continuously operating, the communication infrastructure must be augmented with configuration and monitoring systems. All these services and components are grouped into the *network layer*.

Summarizing, we have that the proposed architecture is based on the following three structuring layers:

- *network*, where all the software components are described, in term of web-components and application logic;
- *application*, described in terms of

execution chains starting from the available multi-tiers web components and coordinated by the application servers;

- *contents*, where the information describing a particular domain are encapsulated in digital documents and collections.

The proposed architecture advantages are: a) ease of deployment on Internet, high reliability and fault-tolerance, and efficient use of the network infrastructures; b) flexibility and generality as needed in order to evolve and meet future needs; c) scalability without fundamental changes in the structure of the resource name spaces.

In the rest of this section, the components are described according to the architecture previously defined and sketched in Figure 1.

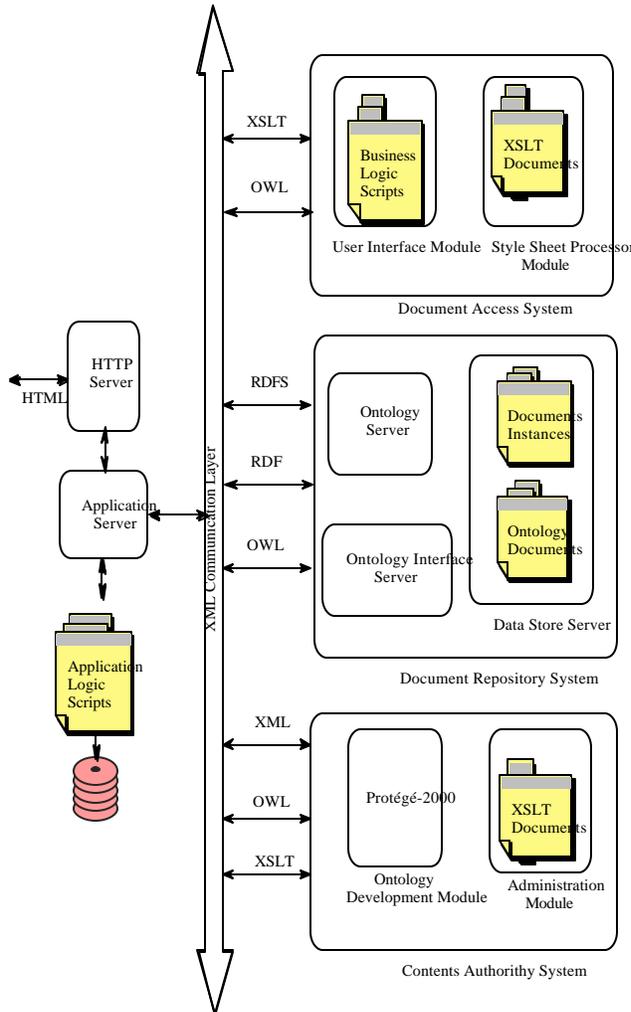


Figure 1: Distributed Contents Management architecture.

### A. The Documents Repository System

A new methodology for describing the documents topics is emerging from the semantic web researches. It is based on the notion of ontology. Ontologies are utilized to define the underlying concepts and the corresponding semantic interpretation that maps terms and descriptions to the concepts. Since ontology-based information technology promises to simplify the interoperability problems, we chose to design the Document Repository System around an ontology server.

In fact, our Document Repository System is built starting from three kinds of servers:

#### Data Store Server

The documents are represented as digital objects together with the associated metadata information. Here, metadata are organized using domain ontology. The Data Store Module is composed of a document media repository, which stores the digital representations of the document contents according to a set of XML applications, and a metadata repository, that stores all the document annotations that are XML-encoded and organized according to RDF model [7] and [17]. This kind of documents structuring and coding strategy makes possible to separate the document layout implementation from its contents.

The Sesame package [14] is the main Data Store Module software component. It is an open source, platform-independent, RDF Schema-based repository, provided with querying facility written in Java. The low level persistent storage is achieved using Postgresql [16], one of most widely used public domain database environment. The Sesame environment offers three different levels of programming interfaces: the client API, for client-server programming; the server API; and the lower level *Storage and Inference Layer* (SAIL) API, for the RDF repositories.

#### Ontology Server

The ontology server provides the Document Repository System with the basis for the semantic interoperability capabilities. Conceptually, it is the most important type of servers since it manages the OWL/RDF [15] schema for the stored data, and determines the interactions with the other servers and/or

modules, through the ontology exchange protocol [10].

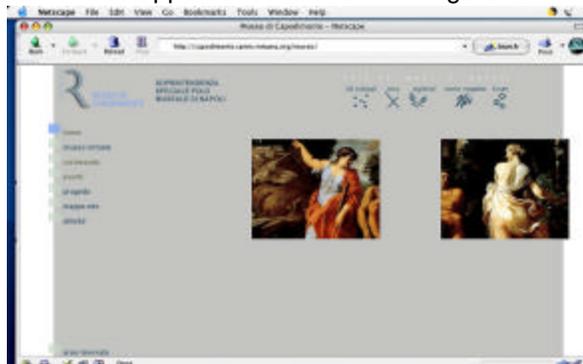
Each ontological feature is associated with a domain ontology; for example, ontologies for artifact, material and techniques have been defined according to the Italian Istituto Centrale di Catalogo e Documentazione (ICCD) standard, adopted by several museums managers to archive art crafts data. The ontology descriptor is an RDF descriptor that summarizes the covered domain. It is used to annotate the documents, for each ontology component. The ontology RDF descriptor and the corresponding ontologies are stored into the metadata repository, and can be accessed through the ontology exchange protocol.

#### *Ontology Interface Server*

The Ontology Interface Server consists of a set of functionalities for walking through the ontology graph and the associated attributes. At runtime, these functionalities are used by the Document Access System to build the user interfaces, the browsing structures, the application services, and so forth. For example, to build the management user interface, it is necessary to create a set of dynamic forms, according to a classification schema, synthesized into the corresponding ontology. The Ontology Interface Server can be queried about the ontology class hierarchy, and/or the class properties, giving back an RDF document that could be transformed into HTML forms.

#### *B. The Document Access System*

The user will interact with the system through a conventional browser; the DRS appears and behaves like a traditional web site whose appearance is shown in Figure 2.



**Figure 2: Home page of participant museums**

Documents must undergo a text processing before to be displayed, and programmed according to a sequence of transformations expressed using the Extensible Stylesheet Language Transformation (XSLT) [6]. The Document Access System manages this document composition process, whose business logic could be summarized as follows: the ontology client makes the first step by extracting the information from the data store and wrapping this information with XML tags. The extraction is done querying the ontology server. The second step involves the application of the appropriate stylesheet transformations to the XML data and thereby the creation of a corresponding HTML page. The foregoing step is carried out by the XSLT package included in the application server. The output of that transformation is the HTML page that is directly sent to the browser.

#### *Style Sheet Processor Module*

This module is responsible for taking RDF data from the data store and converting it to the appropriate HTML document to be presented to the user. The Stylesheet Processor module consists of the Python XSLT package managed by the Zope [18] application server.

#### *User Interface module*

The User Interface module is the communication point between the user and the application. An administrator has the ability to input new information through the system, while a visitor can easily (indirectly) query the document repository through HTML links. This module provides the implementation of ontology clients that extract the needed information from the ontology server.

#### *C. The Contents Authority System*

The Contents Authority provides the museum managers with the possibility of interacting with heterogeneous and distributed document repositories. Actually, it allows for the dynamic construction of collections that could belong to the different repositories. Furthermore, it guarantees the necessary autonomy to museum managers in organizing their contents space.

To achieve these goals the CA is equipped with the following modules:

*Ontology Development Module.* We used the Protégé-2000 ontology editor for developing and editing the ontologies. Thereafter, those ontologies were uploaded into the data store module and used to populate it through the administration module. We developed an extension for the OWL Protégé-2000 Plug-in in order to store the ontology directly on the Data Store Module using the client/server metaphor.

*Administration Module.* The application uses Zope managed forms for inputting new information according to the adopted ontologies. The administration module provides the ability to add new publications or new collection on the document repository. The forms are processed through Zope, the data are transformed into OWL instances, and the latter are sent to the Data Store Module to be made persistent.

For what concerns many communication issues pertaining to the interchange of ontologies, as well as “pieces” of ontologies, we designed and adopted ezXML4OWL, our own ontology representation language [19]. This permits to reduce an OWL ontology in autonomous meaningfully interchangeable objects called OWL-modules. CAS handles such modules in order to manage partial variations of ontologies as well as to merge ontologies coming from different partners. We designed various specific types of OWL-modules and sub-modules and ezXML4OWL is provided with constructs for serializing them in XML elements and documents.

### III. THE MUSEO VIRTUALE DI NAPOLI TEST BED

Usually, the aim of any ordinary museum visitor is something quite different from trying to find certain objects. Visitors would rather want to learn about the past and they experience it with the help of the collections contextual information. In physical exhibitions, the cognitive museum experience is often based on the thematic combination of exhibits and their contextual information. In order to realize how much it would be complex to achieve these goals, the research and development project “Museo Virtuale di Napoli: Rete dei Musei

Napoletani”<sup>1</sup> (REMUNA) is carried out at the Istituto di Cibernetica E. Caianiello. Its main objective is to develop a distributed multimedia contents management environment, to allow for contents integration and management and to facilitate the cooperation among different but correlated knowledge domains. The expected results are an increased museum manager’s synergy based on the information integration, and the deployment of a large distributed document repository system on top of the emerging web technology, using cost affordable hardware, software and networking infrastructures.

As a case study, the collection document repositories of eighteen Neapolitan museums are used. These document repositories use different technologies, have different conceptual schemas and are physically located in different districts of Naples. Each museum is equipped with multimedia information system and communication infrastructures. From the museum managers’ (information providers) perspective each information system allows him to make available the managed artefacts’ information through the REMUNA environment, just after registering them into the system. In fact, during the document registration process, the system extracts metadata from the cultural heritage artifact document description and creates a new digital document that encapsulates the various pieces of metadata about the given artifact. All this information is encapsulated into a digital object that plays the role of a handle for the actual artifact information. No assumption about fixed attributes names’ schemata is taken, so the application builder can create new attributes as needed just modifying the associated ontology without changing the internal database schemata.

The information provider<sup>2</sup> could also organize a set of related documents, in document collections, according to some relationships defined on top of the

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<sup>1</sup> The project “Museo Virtuale di Napoli: Rete dei Musei Napoletani” is supported by Ministero dell’Università, Ricerca e Tecnologia, under contract C29/P12/M03, from here on denoted with REMUNA

<sup>2</sup> In this paper we assume that *information provider* means the responsible, inside the museum organization, of the cultural heritage goods information.

associated ontology. The adopted notion of collection is a recursive one, in the sense that a collection could contain other collections. Each digital document is allowed to belong to multiple collections and may have multiple relationships with other documents. This nesting feature forms the document repository collection graph, and allows the system to deliver more than one logical view of a given digital documents asset.

To assure the necessary operational autonomy to the information provider, without reducing the cooperation opportunities with other information providers, we deployed the Cultural Heritage Content Authority as an intermediate coordination organization that is in charge to register and syndicate document contents, to guarantee their quality. Since the presence of a content authority could create a bottleneck, the notion of delegation was introduced. In other words, the top authority could delegate another organization to operate as Cultural Heritage Contents Authority on its behalf, for a more specific content domain.

#### *IV. CONCLUSION*

This paper describes the methodological choices on which we developed an integrated Web environment, equipped with web components and applications for producing, archiving, and disseminating information about the Neapolitan Cultural Heritage, over Internet. We choose Naples as our test bed since it has been a very active cultural center since the ancient Greek age, was one of the European capitals, until the Italian unification, and still plays an important role in the European heritage.

One of the most interesting technological aspects investigated was how to design document repositories systems that allow the museum manager to organise the cultural heritage heterogeneous information space spread in many autonomous organizations. To cope with this aspect we proposed the Cultural Heritage Content Authority component that is in charge of organizing and structuring the contents of the participating institutions. In other words,

the Cultural Heritage Content Authority does not directly manage contents but manages the rules to be adopted in organizing the contents space on a specified area.

These Cultural Heritage Contents Authority definition and deployment are similar to those of the Publishing Authority used in the "Networked Computer Science Technical Report Library" (NCSTRL) project, started up and carried out at Cornell University [9]. The NCSTRL collection is logically and administratively divided into publishing authorities, and each publishing authority has control over addition and administration of documents in its own sub-collection repositories.

The Ontology Exchange Protocol and tools were implemented to exploit the Multimedia Document Information System federation settlement. This protocol is very similar to the Dienst [9] collection service, where the main difference relies on the fact that in our case the collections are entities built on top of an ontology describing the domain of the documents content and not predefined ones. To a certain degree, our usage is similar to that of the CIMI project [3]. In fact, it has become increasingly evident that simple application-specific standard, such as Dublin Core (DC) [4], cannot satisfy the requirements of communities such as BIBLINK [2] and OAI [13] that need to combine metadata standards for simple resource discovery process.

Our work successfully showed that an RDF data store (Sesame) could be used as a backend document repository for a distributed Contents Management System (CMS). It was clearly laid a framework for possibly implementing semantic capabilities.

As the Semantic Web begins to fully take shape, this type of distributed CMS implementation will enable agents to understand what is actually being presented in distributed CMS, since all content within the system is modeled in machine understandable OWL/RDF.

Starting from these encouraging results we are planning to actively pursue some of the goals foreseen by the Semantic Web Initiative [1], [11], and [12]. For example, to gain more semantic information we are

exploiting pieces of well-known and supported ontologies, like ICOM-CIDOC [8]. Also, more advanced semantic capabilities (searching and browsing) can be implemented. In fact, lastly, with the aid of the underlying ontology, suggested links (both inside and outside the system) are provided to users, while they are browsing the site.

#### ACKNOWLEDGMENT

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# Understanding and Reducing Web Page Latency

Kevin Curran and Noel Broderick

**Abstract - Studies have shown that surfers spend a lot of time impatiently waiting for Web pages to emerge on screen and HCI guidelines indicate ten seconds as the maximum response time before users lose interest. This paper presents research into the observed usage of Web images and the effect on page retrieval times. The prevalent factor that affects how quickly a Web site performs is the type of Web hosting environment that the site is deployed in. Web users are faced with sliding scale of delays in reality, with no one Web page taking the same time to load on two separate occasions. It is arguable that the magnitude and variance of network delay between a client and server are generally proportional to the distance spanned, assuming that all other influencing factors remain constant. Web can tweak their content to reduce the loading time of their sites.**

**Index Terms: Web page latency, Performance measurements, Image compression**

## 1. INTRODUCTION

Web access is the most popular service and statistics from NUA speculated that there are an overwhelming 605 million users online [1]. Evidently, this immense demand placed on the World Wide Web infrastructure has led to reduced bandwidth which is a primary contributor to client latency. Studies have shown that Web users spend a lot of time impatiently waiting for Web pages to emerge on screen. Slow page retrieval times is the most widely reported problems and users prefer Web pages to be presented on a computer screen as quick as one can turn over a new leaf of a book. HCI guidelines indicate ten seconds as the maximum response time before users lose interest [2]. Such delays impact the sites success and are expensive in terms of lost business opportunity or users productivity [3]. Since the Mosaic browser was introduced in 1993 with its ability to display images [4], there was a proliferation in the number of Web pages using a combination of text and image-heavy design.

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The use of images contributes heavily to slow loading sites [5] and is straining the capacity of the Internet further as the current network infrastructure that also supports bandwidth intensive applications such as email, video conferencing and online gaming, will not cope with the stress of end users increasing demand for more bandwidth. Any technique that saves on bandwidth and make browsing more pleasurable should be explored.

This paper presents research into the observed usage of Web images as it is within the control of Web developers and will yield the most value. Findings of the study will provide a better understanding and help to devise a strategy on what can one do to eliminate or at least reduce potentially harmful effects of very slow page retrieval times. The top level domains (TLD), i.e. home pages, of forty seven academic Web sites were chosen. They span across five different countries: UK, Ireland, Canada, USA and Australia. They have many Web users and typically they all hit the same home page. There will be potential students checking out the course prospectus. Perhaps commercial users are looking for consultancy. The five countries under scrutiny have their own private multi-gigabit data communication network reserved specifically for research and education use and are linked to international peer networks.

The first study examines network latency by visiting the Web sites for the first time. The efficiency of cache mechanism in reducing the client latency was also assessed. Latency measurements was obtained from two different sources, from a workstation at the author's institution and from a Web performance monitoring service provided by TraceRT [6]. The second study surveys the academics' Web sites and account for variations in page retrieval times particularly to images which was the interest of this study.

The final study explores image compressions and assesses how efficiently Web developers are optimising images for their Web sites.

Another topic awaiting exploration was to trim the file size of images while retaining visual fidelity.

The effects of reduced image size (in bytes) have on page retrieval times had been looked into.

## 2. NETWORK DELAY COMPONENTS

A modern server uses Path Maximum Transmission Unit Discovery (PMTUD) heuristics to determine the Maximum Segment Size (MSS) which is the safe packet size that can be transmitted. This technique was adopted to address the poor performance and communication failures associated with oversized packets which are fragmented at routers with small MTU [7]. Today, the PMTUD concept is imperfect as it uses the Internet Control Message Protocol (ICMP) which some network administrators view as a threat and block them all, disabling PMTUD, usually without realising it [8]. This led to increased packets overheads due to retransmissions and eventually connection time-outs. Lahey [9], suggested a workaround where after several time-outs, the server network should be reconfigured to accept an altered ICMP packet with the 'Do Not Fragment' bit disabled. Consequently the PMTUD feature is bypassed, but detection can take several seconds each time, and these delays result in a significant, hidden degradation of network performance.

### 2.1 Transmission Control Protocol's (TCP) Flow control

The flow control mechanism of TCP uses slow start and congestion avoidance algorithms as a mechanism to control the data transmission rate. This helps to reduce packets loss caused by congested routers. However, lost packets can be recovered using TCP's retransmission feature, but this incurs added delivery time. The aggressive behaviour of multimedia applications involving audio and video, in which developers employ UDP compounds the problem of congestion. UDP are not TCP friendly and they do not respond to packet drops which typically hint congestions. This aggressive behaviour degrades and even shuts out TCP packets such as Hyper Text Transfer Protocol (HTTP) and prevents them from obtaining their fair share of their bandwidth when they battle for bandwidth over a congested link. Lee et al. [10] examined the use of TCP tunnels at core routers to isolate different types of traffic from one another. Benefits include reduced TCP's retransmission per connected resulting in packets being processed using the same amount of memory resources. This concept is not used extensively on the current Internet infrastructure.

### 2.2 Domain Name Servers (DNS) Lookup

DNS is responsible for translating domain names into an equivalent IP address needed by the Internet's TCP. The latency between DNS request and response is a random variable as the

DNS lookup system uses the client's cache file, the hierarchical nature of the domain name and a set of DNS operating at multiple sites to cooperatively solve the mapping problem. A survey from Men and Mice [11] showed that 68% of the DNS for commercial sites (e.g. .COM zones) has some configuration errors, thus making them vulnerable to security breach and denial of service. The often can be misconfigured. An intelligent DNS management system was recently developed by Liu et al. [12] which offers administrators support in DNS system configuration, problem diagnosis and tutoring,

### 2.3 Protocol

The network delay for Web page loading is dominated by the current version of the HTTP/1.1 standard. It is an application level protocol for transfer of Web contents between clients and servers. Due to increasing Internet traffic, HTTP/1.1 makes inefficient use of the network and suffers from high latencies for reasons such as TCP's three-way handshakes for opening a connection which adds extra round trip time delay and multiple parallel TCP streams which do not share the same congestion avoidance state. Spreitzer et al. [13], have composed a prototype for HTTP 'next generation' which should address these latency issues.

### 2.4 Cache mechanism

Caching mechanisms can exist on a client's local disk, network servers or at Internet Service Provider locations. Its rationale is to assuage congestion, reduce bandwidth consumption, improve retrieval times by temporary storing Web objects closer to the clients and reduce the burden on the site server as it handles fewer requests. Caching is often deliberately defeated as not all Web contents are cacheable. A modern day Web page contains both dynamic and static contents. Dynamic items are non-cacheable and typically they contain interactive and changeable items that provide a far richer experience for users, but they are not happy to wait for them [14]. Cached components characteristically contain items that do not change, i.e. they are static. An intelligent cache engine has emerged recently that serves dynamic elements of Web page and reduces the latency time by 90% [15]. It works by estimating future client's behaviour at a site based on pass and present access patterns. The downside with caching is that if the user does not use the cached items, then congestion may have been caused needlessly.

## 2.5 File size of embedded objects

Recommendations that were made to improve Web page designs have positive impact to page retrieval times as well as usability. The adoption of Cascaded Style Sheets (CSS) [16] and more compact image representations, Portable Network Graphics (PNG) [17], have added value of reducing the file size and speeding up page downloads without sacrificing graphics design [14]. PNG was designed to be successor to the popular GIF files, but it was not until the late 1997 when browser wars came to an end as many old browsers finally caught up and are able to read PNG formats. Another Web image format is JPEG which uses lossy compression.

## 3. EVALUATION

Forty seven TLD sites belonging to worldwide universities were selected for this study. This was comprised of twelve UK sites, ten USA sites, nine Canadian sites, eight Irish sites and eight Australian sites. Universities selected for this research are linked to the NRENs [18], [19], [20], [21]. Information about the network topology for the five NRENs was gathered and checks were made to ensure that there were no intermittent brief outages or reported performance issues. For this study, the response time was obtained from two sources. From the author's institution, the response time was the period it took for the requested Web page to be fully presented on the browser window. This measured the performance of Web pages delivered within the international NRENs infrastructure via the UK's JANET network. The test was conducted using Netscape Navigator 6.2 on Windows 2000 Professional, with a 10Mbit/s link to JANET. The experimental method was to request a Web page via specially prepared bookmarks. The download timer in Navigator gave the loading time measurements. Two types of request were used:

1. *First time retrieval*: equivalent to a browser visiting a site for the first time. In Navigator the memory and file cache was cleared.
2. *Cache request*: equivalent to revisiting a site online. The static contents were already available in the client's local cache. This meant that static items are displayed on screen more quickly the next time the page is visited and any dynamic items had to be retrieved from the server.

To account for network idiosyncrasies, latency measurement was collected three times and the measured mean was used. The second measurement source was provided by TraceRT. This service was used to measure the speediness of Web sites as seen from six measurement points (called agents) around the

world. The agents are commercial sites and operate outside the NRENs infrastructure. To account for changing server loads and different time zones, the response time investigations was repeated at approximately the same time in the morning, afternoon and evening (in British Summer Time) for seven consecutive days. Long latency link may have a major influence on the total response time for serving a set of Web page objects from the server to the client. The location of site servers was gathered using a diagnostic tool from NeoTrace Express [22]. To account for variations in retrieval times, statistics on the quantity and size of objects that a Web page contains was collated. The number of embedded objects gave an indication of how many server requests must be made and the file size implicates how quickly the heterogeneous network could present them.

Using GIF files that were extracted from the sample sites, the author tried to re-express these images into compact PNG formats. This was done by the means of a batch image conversion tool, ReaConverter Pro v3.4 [23]. Where possible an attempt was made to create transparent PNGs so that images could rely on the background colour of the site's home page. With Adobe Photoshop 8.0, all JPEG images were optimised for the Web using sixty as the quality factor. The optimised JPEG images were compared with the original to see if Web developers have used appropriate compressions. Next, the author trimmed the file size of optimised JPEG images by saving them, unchanged, as JPEG in Microsoft Paint v5.1. The file size for the new PNG, optimised JPEG and trimmed JPEG images was recorded.

### 3.1 Thresholds of interest

Web users tend to be sensitive to variations in loading delays and for this study there are two natural thresholds of interests: that of insignificant and that of pain. Delays that are less than the threshold of insignificant are not minded by the user. Delays that is greater than the threshold of pain result in users abandoning the system. Delays that fall between these thresholds normally results in a minor complaint from the user. Absolute values for these natural thresholds are not known as patience varies from user to user. In this study, values for insignificant and 'pain' threshold were taken to be three seconds and eight seconds, respectively.

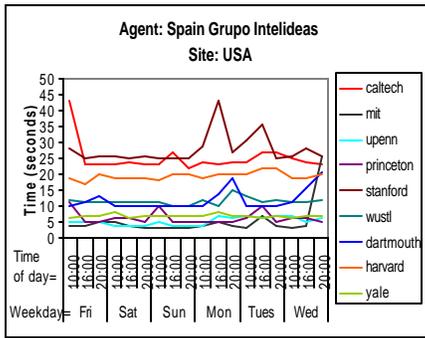


Figure 2: Speed of USA's Web sites as seen by an agent in Spain.

#### 4. RESULTS

The first time retrieval and cache validation tests for Web pages downloaded via the JANET infrastructure is shown in Figure 1. The author found no obvious relationship with the file sizes or image counts to justify the response times. Long latency link could possibly explain the high retrieval times as experienced from two USA's site servers, 'Caltech' and 'Stanford', as they are the only site servers in the west coast of USA. Other USA sites are located in the east. Figure 2 confirms the speed (in seconds) of nine USA's Web sites as observed by a commercial agent in Spain.

While the Internet was behaving in a fluctuating manner it can be seen that five USA's sites would have missed out on possible business opportunities as they were in the pain zone. The other four sites fell inside the whinge sector. USA lags behind Spain by five to eight hours, therefore a safe assumption was made whereby on Monday afternoon (Spanish time) the condition of site servers became heavy as web users in the USA went online after the weekend break. Comparing the latency results shown in Figure 1 and 2, pages requested within the NREN infrastructure was presented much quicker. To seek out additional reasons behind the sliding scale of delays as seen in Figure 1 and 2, a packet sniffer [24] was used to count the number of packets involved for the transmission of images. When a sniffer was applied during individual requests for images from sample site servers, some interesting effects were noticed. Based on visual inspection of Figure 3, it has been noticed that no two images of equal size (in bytes), from five Australian's sites, arrived at the author's workstation with the same number of packets. As the file size of images increased the packet counts increased exponentially and without doubt so did the image loading time. Similar behaviours have been observed for sample sites in USA, Canada, UK and Ireland. Dissimilar PMTUD schemes used by site servers, server loads, congestion levels or fragmentation of oversized packets may have attributed to varying packet counts.

The outcome of the first time retrieval tests (from Figure 1) showed that five sites were in the pain sector, ten sites fell inside the whinge region and twenty eight sites in the insignificant zone. With the cache mechanism in place, the author noticed that for the five sites that were in the pain sector, one went to the insignificant zone while three moved to the whinge region. The last one stayed, but its response time improved by ten seconds. Three cache misses took place, but the user would not have cared or noticed because the average added time was 236ms and the affected sites did not shift from the insignificant zone. The cache system was very effective in reducing the retrieval times and made Web browsing more pleasurable. While cache misses augment page retrieval times the author carried out a survey to obtain the frequency of these misses.

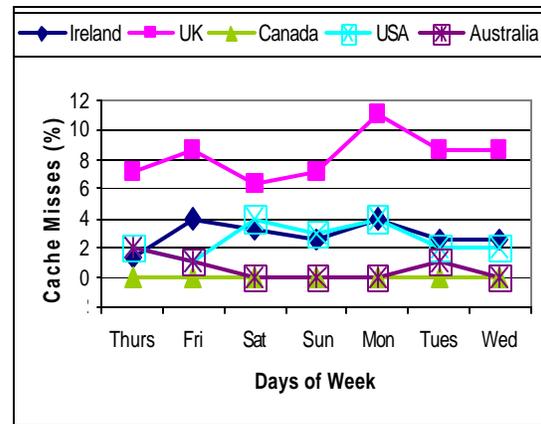


Figure 4: cache misses within the international NREN infrastructures.

The results are depicted in Figure 4. While there were no cache misses for Canada, UK had the highest percentage of misses due to a large number of sites containing dynamic items which had to be fetch from the site servers when the page was reloaded. It has been noticed that new items may increase the overall page size and this impacts how quickly the Internet could present the page's contents. The author took a peek at Navigator's temporary cache folder and noticed that only image files are readily cached than text files.

Forty seven test sites held a total of static 904 GIF images. Of these only 476 were successfully converted to PNG format. GIF images that were successfully converted totalled 1,048,299 bytes, while PNG equivalent resulted in a total 919,298 bytes, saving 129,001 bytes. The savings are modest because many of the images are very small. PNG conversion did not perform well on very low depth images in the sub-900 bytes category. It is thought that checksums and related data were added which made the file bigger. It is clear from Figure 5 that some sites in

the USA did not Web-optimize their JPEG images. By optimizing the JPEG images and trimming the file size, the author was able to compress 452,250 bytes of original JPEG images down to 194,150 bytes. This represents a saving of 57.1%. Similar behaviour was also observed for sites in Australia, Canada, UK and Ireland. It is thought that by saving the optimized JPEG images in Microsoft Paint, it removed supporting bytes used by Photoshop. Based at the author's institution there are two public Web sites, each containing thirteen images. The total page size for Site A is 83.3KB and is composed of six GIFs and seven original JPEG images. Site B totalled at 51.9KB includes matching images as in Site A, but only compressed versions are used. The effects of reduced file size to loading times as seen by six foreign agents are depicted in Figure 6. It is evident that by making attempts to reduce file size, it will reduce user visible latency.

## 5. CONCLUSION

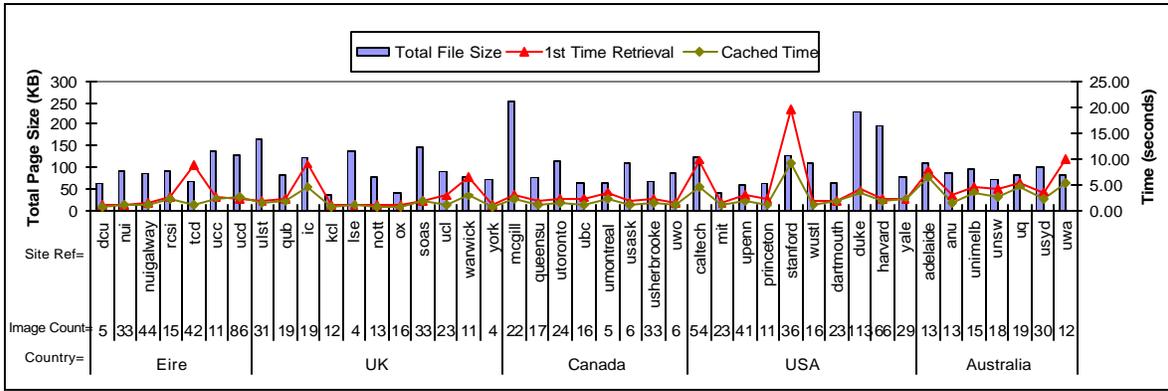
The prevalent factor that affects how quickly a Web site performs is the type of Web hosting environment that the site is deployed in. Web users are faced with sliding scale of delays in reality, with no one Web page taking the same time to load on two separate occasions. It is the number of application packets, not bytes, and the number of simultaneous users of the part of the Internet involved in the connection that determines the Web page latency and satisfaction levels. If Web developers take the time to tweak different file sections then the loading time of their Web sites will fall dramatically. While it is highly documented that PNG is a more compact image representation, they are not suited on low depth images in the sub-900 bytes group. Of the 904 GIF images sampled, 48% of them fell in the sub-900 group, but they do not graphically capture the meaning of the page. To achieve the graphical and functional goals of web sites within the technological limitations of the Internet infrastructure, the author wish to research the possibility of developing a web-authoring tool that will trim the file size of images autonomously. One technique as was adopted in this paper is to convert GIF images above 1KB to PNG formats. In addition, using known limitations of the human eye, the tool can further optimize the JPEG images to acceptable quality levels. An option would be available for developers to override these features. One drawback with these

techniques is that they will stress memory resources as they will contain both original and compressed images.

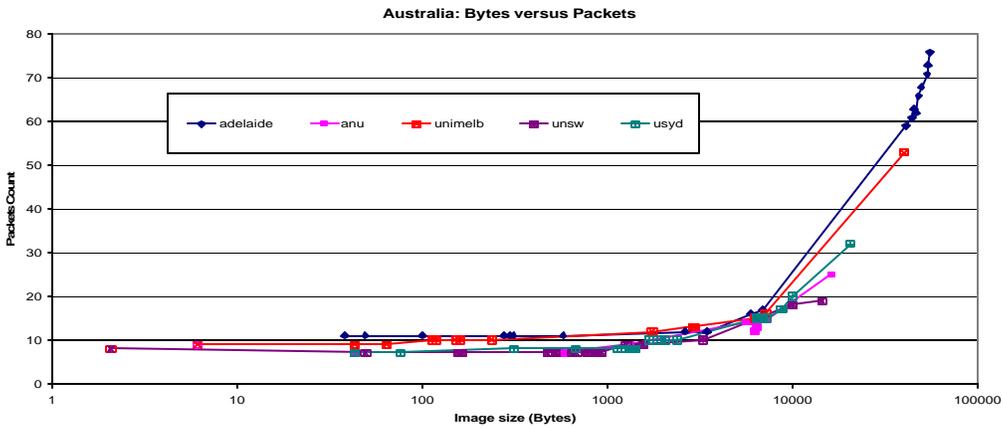
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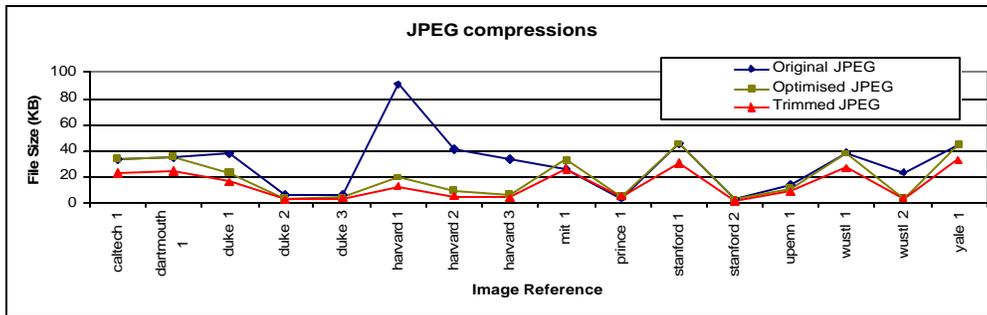
## Appendix



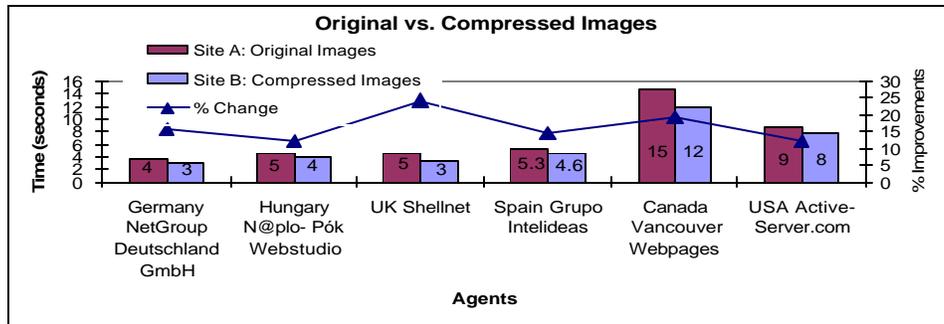
**Figure 1: First time retrieval and cache validation response time results (for pages requested within the NREs). Including image counts with histograms showing the total page sizes (in KB).**



**Figure 3: Australia: Image Size (in Bytes) versus Packet count from five site server**



**Figure 5: Effects of compression to JPEG images held by universities in the USA.**



**Figure 6: Effects of image compression to page loading times as seen by six agents.**

# Modelling and Analysis of Agent-Based Electronic Marketplaces

Giancarlo Fortino, Alfredo Garro, and Wilma Russo

**Abstract**—*In this paper, an approach for modelling and analysing e-Marketplaces based on agents is proposed. The approach is founded on a Statecharts-based specification language and on a Java-based, discrete event simulation framework. The former allows for the modelling of the behaviour of the main agents (stationary and mobile) of an e-Marketplace along with their interaction protocols. The latter supports the execution through simulation of agent-based e-Marketplace models. The approach is exemplified by defining and simulating a consumer-driven e-Marketplace model which offers mobile agent-based services for searching and buying goods. The simulation phase enabled validation of the e-marketplace model and evaluation of the performances of different kinds of mobile consumer agents.*

**Index Terms**— *Mobile Agents, Statecharts, Agent-based e-Marketplace, Event-driven Simulation, Performance Evaluation, Java*

## 1. INTRODUCTION

**E**LECTRONIC Marketplaces (e-Marketplaces) are e-commerce environments which offer new channels and business models for buyers and sellers to effectively and efficiently trade goods and services over the Internet [12]. To support intelligent and automated e-commerce services, new enabling infrastructures are needed.

These infrastructures can be effectively developed using the emerging Agent technology and paradigm [10] along with XML-based emerging standards such as ebXML [1]. Software Agents retain the potential to structure, design and build e-commerce systems which require complex interactions between autonomous distributed components [13]. In particular, Agent-mediated e-commerce is concerned with providing agent-based solutions which support different stages of the trading processes in e-commerce such as needs identification, product brokering, merchant brokering, contract negotiation and agreement, payment and delivery, and service and evaluation [9]. Moreover, the distinctive capability of peculiar agents, called “mobile agents” [11], to move across a networked e-commerce environment can extend that support by enabling advanced e-commerce solutions such as location-aware shopping, mobile and networked comparison shopping, mobile auction bidding, and mobile contract negotiation. In addition, with respect to the traditional paradigms (C/S, REV, COD), the exploitation of mobile agents allows for conservation of bandwidth, reduction of latency, protocol encapsulation, asynchronous and autonomous distributed execution, dynamic adaptation, seamless integration of heterogeneous system, robustness and fault tolerance [11]. Although none of these strengths are unique to mobile agents, no competing technique shares all of them.

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To date, a multitude of agent- and mobile agent-based e-commerce applications and systems have been developed [9], which basically allow for the creation of even complex e-Marketplaces on the Internet. However, to more effectively evaluate such solutions and, more generally, the benefits of using Agents to develop e-Marketplaces proper methodologies and tools are required. Such methodologies and tools should allow to validate, evaluate and compare the effectiveness and the efficiency of agent-mediated e-Marketplace models, mechanisms, policies and protocols before their actual implementation and deployment, saving development efforts and identifying better solutions.

In [7], an agent-based framework for e-commerce simulation games has been developed by using Zeus, a Java-based multi-agent system developed at the British Telecom Lab. Its goal is to evaluate through multi-player shopping games, in which agents represent sellers, buyers, brokers and services of various kinds, the potential consequences of novel combinations of market models, business strategies and new e-services. In [14], an infrastructure for Internet e-Marketplaces, based on Aglets mobile agents which supports real commercial activities carried out by consumers, agents and merchants, has been proposed. Its goals is not only to provide an advanced e-commerce service, but also to evaluate several dispatching models for mobile agents.

Although useful insights into new models and strategies can be gained by playing properly constructed games or by evaluating real applications, discrete event simulators are highly required to evaluate how these systems work on scales much larger than the scales achievable in games or in real applications where humans are involved. Nevertheless, few research efforts have been devoted to analysing agent-mediated e-Marketplaces by means of discrete event simulation.

This paper proposes an approach to the modelling and analysis of agent-based e-Marketplaces which centres on a Statecharts-based methodology for the simulation of mobile agent-based

applications and systems [3]. The approach is exemplified by defining and simulating a consumer-driven e-marketplace model, inspired by the system presented in [14], which offers mobile agent-based services for searching and buying goods.

The remainder of the paper is organized as follows. In section 2, a Statecharts-based approach for modelling and simulating agent-based systems is presented. Section 3 shows the application of the approach for modelling a consumer-driven, mobile agent-based e-marketplace. In section 4 a simulation scenario of the defined e-Marketplace model is described and evaluated. Finally, conclusions are drawn.

## 2. AN APPROACH FOR MODELLING AND SIMULATING AGENT-BASED SYSTEMS

The proposed approach considers as the starting point a high-level model of the agent-based system that was previously obtained using agent-oriented methodologies [5] covering the phases of requirements capture, analysis and high-level design (see Fig. 1). This model can be expressed by a set of Agent Types (AT) which embody activity and offer services, and by a set of Logical Communication Links (LCL) among agent types which embody interaction protocols.

The approach [3] consists of three phases: Detailed Design, Coding and Simulation.

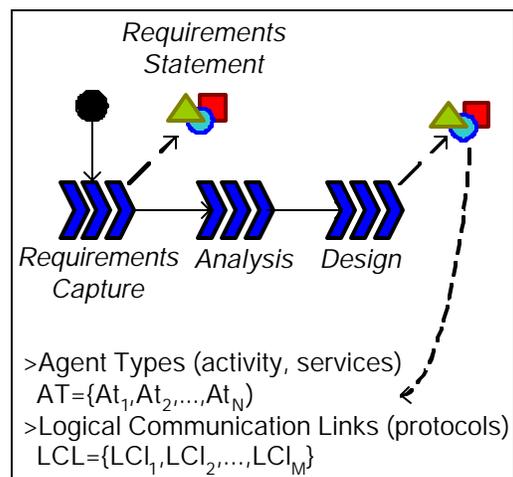


Figure 1. Requirements Capture, Analysis and High-Level Design.

### A. Detailed Design

The *detailed design* of the high-level model of the agent-based system is achieved through the visual specification of the behaviour of the agent types which embodies the definition of activity, services and interaction protocols. Visual specification is carried out using the Distilled StateCharts (DSC) formalism [4], derived from Statecharts [8], that allows for the modelling of the behaviour of lightweight agents, i.e. event-driven, single-threaded, capable of transparent migration, and executing chains of atomic actions.

The specification of the behaviour ( $Abeh(At_i)$ ) of a lightweight agent type is carried out according to the FIPA-compliant agent behavioural template [6], reported in Fig. 2, which is a statechart consisting of a set of basic states (Initiated, Transit, Waiting, Suspended, and Active) and transitions labelled by events. In particular, an agent performs its computation and interaction activity in the ADSC (ACTIVE DSC) composite state, inside the Active state, which is to be refined by the agent designer. The presence of the deep history connector ( $H^*$ ) inside the Active state allows for the transparent migration of the lightweight agent as detailed in [4]. The  $Abeh(At_i)$  therefore consists of two parts: (i) a statechart ( $Sbeh(At_i)$ ) which incorporates activity and interactions, and (ii) the related set of events ( $Ebeh(At_i)$ ) to be handled which trigger state transitions in  $Sbeh(At_i)$ .

$$Abeh = \{Abeh(At_1), Abeh(At_2), \dots, Abeh(At_N)\}$$

$$Abeh(At_i) = \langle Sbeh(At_i), Ebeh(At_i) \rangle$$

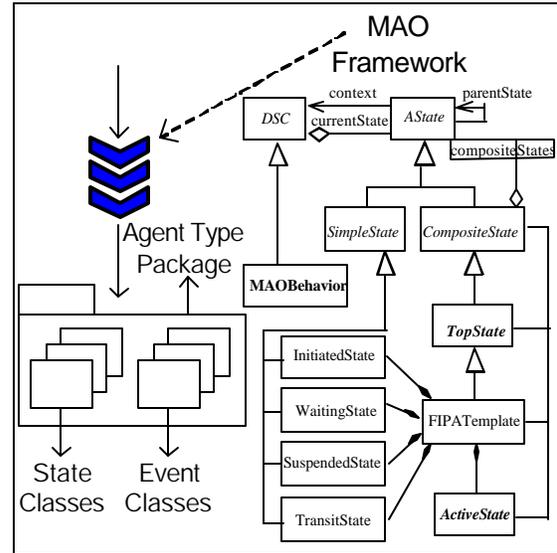
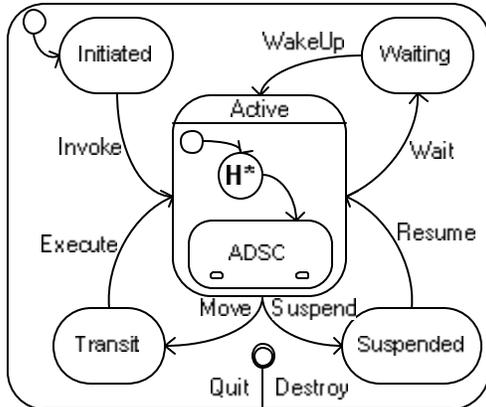


Figure 3. The Coding phase.

### C. Simulation

The *simulation* of the agent-based system (see Fig. 4) is accomplished by means of a Java-based discrete event simulation framework for agent-based systems. Using this framework, an agent-based complex system can be easily validated and evaluated by defining a *simulator program* along with suitable test cases and performance measurements.

In particular, the *simulation engine* of the framework provides support for the: (i) execution of agents by interleaving their events processing, (ii) interchange of events among agents, (iii) migration of agents, and (iv) the clustering of agents into Agent Servers connected by a Logical Network.

The basic simulation entities offered by the framework are:

- the AgentServer, which is an object representing the agent server hosting mobile and stationary agents;
- the Agent, which is an object representing a stationary or a mobile agent ( $A_j$ ) and including a pair of objects:  $\langle Id_j, Abeh_j(At_i) \rangle$ , where  $Id_j$  is the agent identifier and  $Abeh_j(At_i)$  is the *MAOBehavior object* related to the agent type  $At_i$ ;
- the VirtualNetwork, which represents the logical network of hosts on which an AgentServer is mapped;
- the UserAgent, which is an object representing a user. A UserAgent, which is directly connected to an AgentServer, can create, launch and interact with Agents;
- the UserAgentGenerator, which is an object modelling the process of generation of a UserAgent.

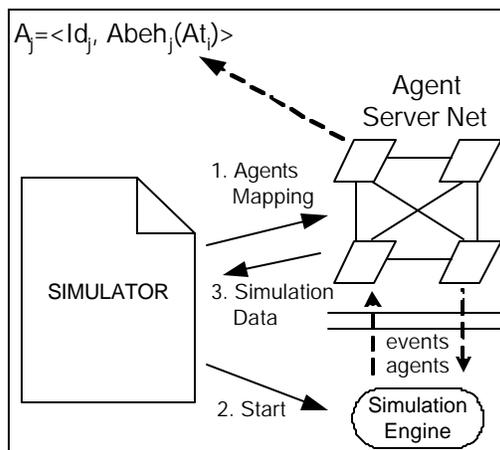


Figure 4. The Simulation phase.

In order to provide an high-level exemplification of how to construct a simulator without going into programming details, consider the following application scenario to analyze. A user is connected through a low-bandwidth link to a remote server which belongs to a fully-connected network of agent servers with higher-bandwidth links. The user sends a mobile agent to the connected remote server where the mobile agent is equipped with an itinerary (i.e. a set of agent server to be visited) provided by a stationary agent. The task of the mobile agent is to travel along

the itinerary, perform some local computation and, finally, come back and report to its owner (i.e. the user created it). The purpose of the simulation is to analyze the average completion time of the mobile agent.

The simulator program can be constructed in the following steps:

- (1) creation of the VirtualNetwork object which is constructed as a set of server nodes completely connected through high-bandwidth links;
- (2) creation of the AgentServer objects and mapping of these objects onto distinct server nodes of the VirtualNetwork object;
- (3) creation of the UserAgent object, which contains the code for the creation of the specific mobile agent (a purposely defined Agent object) and the code for the computation of the mobile agent completion time by marking the instants in time of the departure and arrival of the mobile agent, and binding of the UserAgent object to an AgentServer object through a low-bandwidth connection;
- (4) creation of the stationary Agent object providing the itinerary and mapping of this object onto the AgentServer object to which the UserAgent object is bound;
- (5) creation and insertion of the Invoke event directed to the UserAgent object into the event queue inside the simulation engine;
- (6) initialization of the discrete-event clock and start of the simulation engine.

### 3. MODELLING AN AGENT-BASED ELECTRONIC MARKETPLACE

A consumer-driven e-Marketplace is an e-Marketplace in which the exchange of goods is driven by the consumers that wish to buy a product. The modelled agent-based e-Marketplace, inspired by the system presented in [14], consists of a set of both stationary and mobile agents which provides basic services for the buying and selling of goods.

Identification of the agent types along with their activity and of the logical communication links among the agent types along with their interaction patterns, was carried out by using Gaia [15].

Gaia is a methodology which has been

specifically tailored to the analysis and design of agent-based systems. It is founded on the view of a multi-agent system as a computational organisation composed of a number of autonomous interactive agents which play one or more specific roles. Gaia drives the designer of an agent-based application to obtain the aforementioned identification through the construction of the following set of models:

(i) the *Prototypical Roles Model*, the *Interactions Model* and the *Roles Model (analysis models)*, which identify the roles occurring in the system and model interactions between the roles identified;

(ii) the *Agent Model*, the *Services Model* and the *Acquaintance Model (design models)*, which, on the basis of the analysis models, define the types of agents in the system along with the services, the activities, and the logical communication paths of such agents.

Figure 5 reports the logical structure (or *acquaintance model*) of the agent-based e-Marketplace, highlighting the identified agent types and the logical communication links among them. In the following sections, the functionality of each agent type, the workflow of the system along with the interactions among the agent types, the different kinds of mobile consumer agents, and the DSC specification of a model of mobile consumer agent are illustrated.

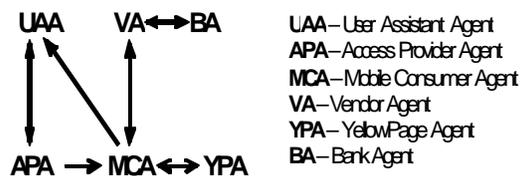


Figure 5. Logical structure of the agent-based e-Marketplace.

#### D. Types of Agents

*User Assistant Agent (UAA)*. An UAA is associated with a user and assists her/him in: (i) looking for a specific product that meets her/his needs; (ii) buying the product according to a specific buying policy.

*Access Provider Agent (APA)*. An APA

represents the entry point of the e-Marketplace. It receives requests for buying a product from a registered UAA and fulfills them by generating a specific Mobile Consumer Agent (MCA).

*Mobile Consumer Agent (MCA)*. A MCA is an autonomous mobile agent that deals with the searching, contracting, evaluation, and the payment of goods. In order to buy a product, a MCA is equipped with a wallet containing a limited amount of e-cash (or “bills”).

*Vendor Agent (VA)*. A VA represents the vendor of specific goods.

*YellowPage Agent (YPA)*. A YPA represents an entry point of the federated yellow pages service (or “Yellow Pages”) which provides the location of agents selling a given product. The following organizations of Yellow Pages were established:

- Centralized: each YPA stores a complete list of VA agents;
- One Neighbour Federated: each YPA stores a list of VA agents and keeps a reference to only one other YPA;
- M-Neighbours Federated: each YPA stores a list of VA agents and keeps a list of at most M YPA agents.

*Bank Agent (BA)*. A Bank Agent represents a reference bank of MCA and VA agents. Bills owned by such agents are unique, cryptographically signed documents issued by one of the accredited banks. A bill can be represented by a few bytes of information containing: the name of the bank, the amount of the bill, the unique bill identifier, and the bank’s signature needed to check the authenticity of the bill.

#### E. System Workflow

The system workflow is structured in the following phases:

1. *Request Input*. When users wish to buy a product, they interact with their associated UAA which is delegated the buying task by specifying a set of buying parameters: product description, maximum price ( $P_{MAX}$ ), Searching Policy (SP) and Buying Policy (BP). Users is notified by their UAA about the task results as soon as the task is completed. To perform its task an UAA contacts the APA with which it is

registered and submits a request containing the product parameters specified by the user. If the UAA is trustworthy (i.e. from a commercial and security viewpoint [14]), the APA accepts the request and creates a specific MCA by passing along the product parameters and the location of the initial YPA to be contacted.

2. *Searching.* The MCA obtains a list of locations of VA agents which sell the requested product by using the Yellow Pages. Searching can be carried out by adopting one of the following searching policies:
  - ALL: all YPA agents are contacted;
  - PARTIAL (PA): a subset of YPA agents are contacted;
  - ONE-SHOT (OS): only one YPA is contacted.
3. *Contracting & Evaluation.* The MCA interacts with the VA agents in the obtained list to request an offer for the desired product ( $P_{offer}$ ), evaluates the received offers, and selects an offer, if any, for which the price is acceptable (i.e.,  $P_{offer}=P_{MAX}$ ) according to the following buying policies:
  - Minimum Price (MP): the MCA first interacts with all the VA agents to look for the lowest price of the product; then, it buys the product from the VA which offers it at the lowest acceptable price;
  - First Shot (FS): the MCA interacts with the VA agents until it obtains an offer for the product at an acceptable price; then, it buys the product;
  - Fixed Trials (FT): the MCA interacts with a given number of VA agents and buys the product from the VA which offers it at the lowest acceptable price;
  - Random Trials (RT): the MCA interacts with a random number of VA agents and buys the product from the VA which offers it at the lowest acceptable price.
4. *Payment.* The MCA moves to the location of the selected VA and pays the desired product using a given amount of bills. The following basic protocol is used to execute the money transaction

between the MCA and the VA: (i) the MCA gives the bills to the VA; (ii) the VA sends the bills to its BA; (iii) the BA validates the authenticity of the bills, exempted them from re-use, and, finally, issues an amount of bills equal to that previously received to the VA; (iv) the VA notifies the MCA.

5. *Reporting.* The MCA reports the buying result to the UAA. On the basis of an unsuccessful buying result (*vendor not found, offers not acceptable*) the user can submit a new request either raising  $P_{MAX}$  or using a different combination of searching and buying policies.

#### F. Models of Mobile Consumer Agents

A behaviour model for the MCA can be defined on the basis of a tuple:  $\langle SP, BP, TM \rangle$ , where SP is a searching policy in  $\{ALL, PA, OS\}$ , BP is a buying policy in  $\{MP, FS, FT, RT\}$ , and TM is a task execution model. Two different task execution models were defined:

- *Itinerary:* the Searching and Contracting & Evaluation phases are performed by a single MCA which fulfils its task by sequentially moving from one location to another within the e-Marketplace;
- *Parallel:* the Searching and Contracting & Evaluation phases are performed by a set of auto-coordinating mobile agents in a parallel way. The MCA is able to generate a set of children (generically called workers) and to dispatch them to different locations; the workers can, in turn, spawn other workers.

An MCA task execution model is chosen by the APA when it accepts a user input request; the choice can depend on the pair  $\langle SP, BP \rangle$  selected by the user and on the e-Marketplace characteristics. If the chosen task execution model is of the *Parallel* type then the MCA is named PCA (*Parallel Consumer Agent*) otherwise if the chosen task execution model is of the *Itinerary* type then the MCA is named ICA (*Itinerary Consumer Agent*). Therefore, a *PCA model* is defined by a tuple  $\langle SP, BP, parallel \rangle$  whereas an *ICA model* is defined by a tuple  $\langle SP, BP, itinerary \rangle$ .

### G. Programming the Mobile Consumer Agents

The DSC specification of the defined PCA model (or simply PCA) is reported in Fig. 6. The defined ICA model can be seen as a particular case of the PCA. With reference to Fig. 6, it is worth pointing out that:

- events are asynchronously received and processed according to a run-to-completion semantics (i.e. an event can be processed only if the processing of the previous event is fully completed);
- the received events can be asynchronously generated by the agent itself (internal events) or by other agents (external events) through the primitive `generate(<mevent>(<param>))`, where `mevent` is an event instance and `param` is the list of formal parameters of `mevent` including the identifiers of the event sender and of the event target, and (possibly) a list of event parameters.

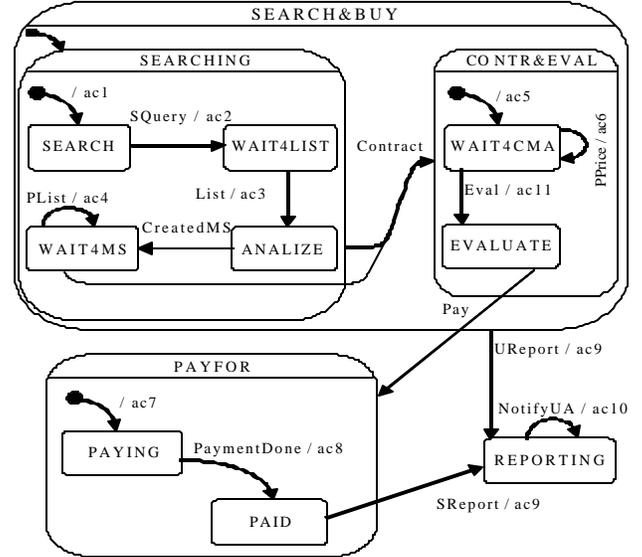
The PCA accomplishes the searching phase in the SEARCHING state.

In particular, as soon as the PCA is created, it moves (`ac1`) to the first YPA location and locally interacts (`ac2`) with the YPATarget by sending it the `VAListQuery` event.

The YPATarget replies to the PCA with the `List` event which can contain a list of VA agents with linked YPA agents.

After processing the reply (`ac3`), the PCA can do one of the following:

- create an Itinerary Searcher Mobile Agent (ISMA), which sequentially moves from one YPA location to another, if the Yellow Pages are of the One-Neighbour Federated type, and passes (`ac4`) into the contracting phase as soon as a `PList` event sent by the ISMA is received. The `PList` event contains the partial list of vendors collected by the spawned agent. It is worth noting that the adoption of the ISMA to carry out the searching task can improve efficiency since an ISMA is *lighter* than a PCA;



```

ac1 : generate(new Move(self(), YPATarget.getCurrLocation()));
      generate(new SQuery(self()));
ac2 : generate(new VAListQuery(self(), YPATarget, valListQuery));
ac3 : List reply = (List)mevent; proc = processInitialYPAREply(reply);
      if (proc.createISMA()) sa1();
      else if (proc.createSSMA()) sa2();
      else if (proc.noVendors()) sa3();
      else sa4();
sa1 : generate(new Create(self(), "ISMA", nextYPATarget));
      generate(new CreatedMS(self()));
sa2 : for (int i=0; i<ypaList.size(), i++)
      generate(new Create(self(), "SSMA", ypaList.elementAt(i)));
      generate(new CreatedMS(self()));
sa3 : generate(new URReport(self()));
sa4 : generate(new Contract(self()));
ac4 : PList reply = (PList)mevent; res = processMSReply(reply);
      if (res.contract()) sa4();
      else if (res.noVendors()) sa3();
ac5 : for (int i=0; i<valList.size(), i++)
      generate(new Create(self(), "CMA", valList.elementAt(i)));
ac6 : PPrice offer = (PPrice)mevent; eval = evaluateOffer(offer);
      if (eval.buy()) generate(new Eval(self()));
      else if (eval.noBuy()) sa3();
ac7 : bills = prepareBills(price);
      generate(new PayFor(self(), VATarget, bills));
ac8 : nbills = nbills - eval.price();
      generate(new SReport(self()));
ac9 : generate(new Move(self(), self().getHomeLocation()));
      generate(new NotifyUA(self()));
ac10.reportTR();
ac11: generate(new Move(self(), VATarget.getCurrLocation()));
      generate(new Pay(self()));

```

ac = action chain  
sa = sub-action

Figure 6. ADSC of the behaviour of the PCA.

- create M Spawning Searcher Mobile Agents (SSMAs), if the Yellow Pages are organised according to the M-Neighbours Federated type, and pass (ac4) into the contracting phase when all the *PList* events sent by the directly created SSMA agents are processed. In particular, an SSMA moves to the assigned YPA and, in turn, creates a child SSMA for each reachable YPA. This parallel searching technique generates a spawning tree with SSMA agents as nodes and rooted at the PCA. If an SSMA interacts with a YPA which has already been visited by an SSMA belonging to the same spawning tree, the YPA notifies the SSMA which comes back to its parent;
- directly pass into the contracting phase if the organization of the Yellow Pages is Centralized;
- report an unsuccessful search to the UAA.

The contracting phase accomplished in the *CONTRANDEVAL* state involves the creation of a Contractor Mobile Agent (CMA) for each VA in the *vaList*. Each CMA moves to the assigned VA location, contracts with the VA, and finally returns to the PCA location to report. The *evaluateOffer* method, which embeds the buying policy, evaluates the VA offers (*PPrice* events) reported by the CMA agents and generates (ac6) a decision about when and from which VA to purchase. In the *PAYFOR* state the PCA pays (ac7) the VA using the *PayFor* event which contains the bills.

After receiving the *PaymentDone* event, the PCA passes (ac8) into the *REPORTING* state from where it moves back (ac9) to the original APA location and finally reports (ac10) to its UAA.

#### 4. SIMULATION OF THE AGENT-BASED ELECTRONIC MARKETPLACE

The primary goal of the simulation phase which was performed was to validate the defined agent-based e-Marketplace model and particularly:

- (i) the behaviour of each type of agent,
- (ii) the different models of MCA agents in each type of the Yellow Pages organizations, and
- (iii) the agent interactions over the logical communication links.

The second goal of the performed simulation phase was to better understand the effectiveness of the simulation for evaluating the performances of different agent-mediated e-Marketplaces solutions. To this purpose, the completion time of the buying task was individuated as the main performance index. In particular, with reference to the proposed model, the completion time of ICA and PCA was evaluated.

The simulation and analysis parameters are presented in Table 1.

**Table 1.**  
**Simulation and Analysis parameters**

$N_{VA}$	Number of VA agents
$N_{YPA}$	Number of YPA agents
YPO	Yellow Pages Organization type: {Centralized, 1-Neighbour, 2-Neighbour}
$\delta_{MA}$	Link delay between two adjacent nodes for transmitting an agent
$\delta_{MSG}$	Link delay between two adjacent nodes for transmitting a message
$T_C = T_{REPORT} - T_{CREATION}$	Completion time of the MCA, where $T_{CREATION}$ is the time of the MCA creation and $T_{REPORT}$ is the time of the MCA report

The simulated e-Marketplace was set up as follows:

- each stationary agent (UAA, APA, YPA, VA, BA) executes in a different agent server;
- the agent servers are mapped onto different network nodes which are completely connected through links which have the same characteristics. The communication delay ( $d$ ) on a network link is modelled as a lognormally distributed random variable with a mean,  $\mu$ , and, standard deviation,  $s$  [2];
- each UAA is connected to only one APA;
- the price of a product, which is uniformly distributed between a minimum ( $PP_{MIN}$ ) and a maximum ( $PP_{MAX}$ ) price, is set in each VA at initialization time and is never changed; thus the VA agents adopt a fixed-pricing policy to sell products;
- each YPA manages a list of locations of VA agents selling available products.
- a UAA searches for a desired product, which always exists in the e-Marketplace, and is willing to pay a price  $P_{MAX}$  for the desired product which can be any value uniformly distributed between  $PP_{MAX}$  and  $(PP_{MAX}+PP_{MIN})/2$ .

In order to analyze e-Marketplaces having different structures and dimensions, the simulations were run by varying (i) the organization of the Yellow Pages (Centralized, 1-Neighbour and 2-Neighbour organized as a binary tree), (ii) the number of YPA agents in the range [10..1000] and (iii) the number of VA agents in the range [10..10000]. These ranges were chosen for accommodating small as well as large e-Marketplaces. The durations of the performed simulations were specifically set to allow for the completion of the buying task carried out by the MCA.

The results obtained from the simulations allowed to: (a) evaluate which task execution model is more appropriate with respect to SP and BP policies and for the characteristics of the e-Marketplace, and (b) validate the analytical model proposed in [14] regarding the sequential and parallel dispatching of mobile agents.

Regarding to point (a), the ICA performs better than the PCA in the following cases:

- $SP=\{ALL, PA, OS\}$ ,  $BP=FS$ ,

- $YPO=\{Centralized, 1-Neighbour\}$ ;
- $SP=\{PA, OS\}$ ,  $BP=FS$ ,  $YPO=2-Neighbour$ .

Thus, the APA can choose the itinerary task execution model if such cases occur.

Regarding to point (b), the performance evaluation focused on the  $\langle ALL, MP, * \rangle$  models (see section 3.B) since they are the only models of MCA which guarantee both a successful purchase and the best purchase since they are successful at identifying the VA selling the desired product at the minimum price.

The results obtained for the  $\langle ALL, MP, * \rangle$  MCA models over an YPA organization of the binary tree 2-Neighbour type are reported in Fig.7. The results shown in Fig. 7 were obtained with  $N_{YPA}=\{10, 100\}$  and by varying  $N_{VA}$ . In agreement with the analytical model reported in [14], the PCA, due to its parallel dispatching mechanism, outperforms the ICA when  $N_{VA}$  and  $N_{YPA}$  increase.

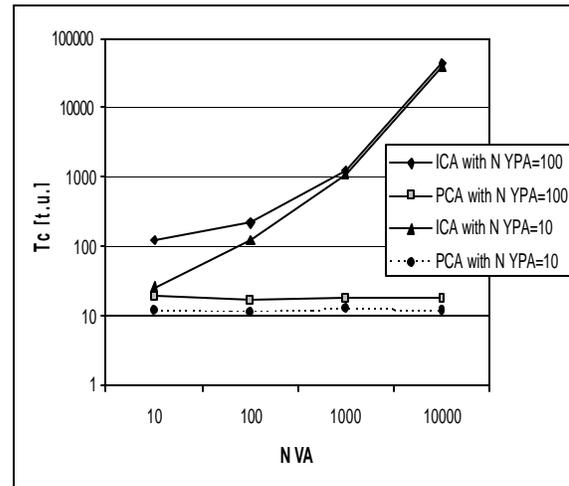


Fig. 7. Performance evaluation of the  $\langle ALL, MP, * \rangle$  models for an e-Marketplace with  $YPO=2-Neighbour$  binary tree type,  $N_{YPA}=\{10, 100\}$  and variable  $N_{VA}$ .

## 5. CONCLUSIONS

Flexible methodologies and tools for the modelling and simulation of agent-based systems are necessary to effectively support agent-oriented software development in complex application domains such as e-Commerce.

This paper has proposed a novel approach centred on Statecharts-based

tools to the modelling and analysis through simulation of agent-based systems. The approach has been exemplified by presenting a case study concerning with the modelling and the simulation of a consumer-driven e-Marketplace.

The approach provides the following valuable advantages:

(i) *Statecharts-based modelling language.* The use of a modelling language based on Statecharts, which are included in UML, reduces the learning curve for modelling due to the pervasive exploitation of UML in Industry and Academia;

(ii) *Validation through simulation.* The use of the simulation to validate agent-based systems before their actual deployment and execution, is strategic. In fact, the simulation, particularly if event-driven, is the only viable means to validate large-scale and complex systems.

In addition, the use of the MAO Framework allows for a seamless translation of the agent behaviour model into code, reducing the discontinuities between modelling and implementation phases.

Current research efforts are geared at modelling multiple integrated marketplaces and addressing through simulation security, efficiency and scalability issues of such large-scale multi agent systems.

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# Introducing a New Infrastructure Element for E-Business Financial Reporting: an Internet Clearinghouse

Max Gottlieb and Boris Stavrovski

**Abstract—** *A new infrastructure element for e-business financial reporting (an internet clearing house) is introduced. It would be advisable to distribute financial reports via an electronic clearinghouse. This method would permit instant access to the reports and assure that these documents could not be modified. The existing reporting frequencies are reviewed, contrasting them with the needs of investors, and the generation of accounting transactions is described. Next, the proposed method of collection and distribution of financial reports as well as their possible analyses by a central electronic clearing house is discussed. Finally, the need for changes of the attestation standards is analyzed, ways to assure the integrity of distributed electronically financial statements are proposed, and the rational sequence of implementation of the new distribution is generated.*

**Index Terms—** *Internet Infrastructure, Financial Reporting, Electronic Clearing House.*

## 1 EXISTING REPORTING FREQUENCY VS. INVESTORS' NEEDS

OVER the decades we experienced great improvements in the areas of data communication and telecommunication. News about events around the world is delivered almost instantly. Similarly, financial news is distributed with minimal

delay. With the fast growth of the securities trade (stocks, bonds, etc.) there is a growing need for fast and reliable financial information.

The basic reliable source of financial information is presently provided by financial reports [1]. Corporations listed on American exchanges are obligated to provide all its shareholders and potential investors with annual audited and quarterly non-audited (but reviewed by auditors) reports. In many European and Asian countries listed companies are required to provide only semiannual and annual reports.

Markets usually respond very quickly to the results presented in financial reports. As such, a report with a lower than expected earnings for a few technology companies in the years 1995 and 2000 resulted in a dramatic drop of stock prices for the entire technology industry. Although more frequent reporting would not have prevented the recent accounting frauds committed by several corporations, it could potentially speed up the discovery of the problems since it is more difficult to manipulate reports a dozen times a year than four times.

The existing frequency of reporting was established in the pre-computer era. One may assume that such reporting periods were the most feasible frequencies at a time of manual, time-consuming preparation of reports.

Today's investors must wait until the end of a quarter to learn about financial results or may receive an occasional release of earlier estimates of corporate earnings. Such

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information is immediately absorbed by the markets, resulting very often in significant changes of security prices. It becomes clear that institutional and individual investors would like to make use of more frequently released financial information. Such information would be most beneficial for individual shareholders since mutual funds and investment houses often obtain information directly from corporations between the reporting periods. Actually, the annual financial reports are delayed more than a quarter from the end of the annual accounting period. It takes several weeks to proof and print these reports, then distribute them by mail. Most annual financial reports reach the investors in the month of March of the next year.

In the summer of 1996, the American Security and Exchange Commission (SEC) adopted a rule permitting the use of the electronic media delivery in compliance with the information delivery requirements of the federal securities law. The term "electronic delivery" refers to transmission of information via facsimile, CD-ROM, electronic mail, electronic bulletin boards, Internet, or computer networks. SEC also issued interpretive guidance on the use of electronic media by broker-dealers, transfer agents, and investment advisors for the delivery of information to their customers.

In year 2000, SEC issued regulation requiring listed companies to make their financial releases available to shareholders at the same time as they become available to investors.

In the following paragraphs we will show that it is possible to greatly increase the frequency of financial reporting without a significant increase in the preparation effort. Also, a method of electronic delivery for financial information will be discussed.

## *2. POSSIBILITIES OF PAPERLESS ACCOUNTING*

In the early stages of the computerized era it was easy to be convinced that we are approaching the so called "paperless society," where the use of the paper for the commerce would be greatly reduced. Ironically, computers, with their vast ability of printing reports and documents, increased the paper usage [2].

Despite this paper glut, the base for electronic transactions is being expanded. Banks and software companies are introducing, the second time around, easier systems for electronic banking. The proliferation of PC's and the increased ease of use of the Internet have drawn over 600 million estimated users, as of the year 2002. The internal electronic mail system is used by virtually all large companies and institutions. The document imaging technology, which converts paper documents into digital form, makes significant inroads into insurance, banking, and other paper-intensive industries. And for years some operations, such as electronic money transfers, have been for the most part "paperless." Another application that could operate in a similar manner, without paper, is financial reporting. Several large corporations, such as General Motors or Microsoft, post their financial statements on their Web sites [3]. Although this information may be helpful to investors, the usage of such sites may be cumbersome to investors since each site is organized in a different fashion, making the search time consuming. Furthermore, such sites may post only financial statements and skip the supplemental information, such as the SEC fillings. A shareholder holding twenty stocks will have to access twenty sites, sometimes several times if the reports were not yet released.

Accounting is a prevalent computerized application in all industries. Frequently paper is being used as the source for its input and almost always as its output. Such manufacturing companies as the SATURN car factory, a division of General Motors, started to eliminate paper documents in dealing with their suppliers. SATURN transfers supply requests via computers, paying suppliers for material based on the number of finished cars.

Although most companies are still lacking a "paperless" electronic link to outside commercial partners, their internal flow of accounting data is usually performed on an electronic medium, either via tapes/disk or increasingly via the Internet or network transfer [4].

3. PROPOSED METHOD FOR DISTRIBUTION OF FINANCIAL REPORTS (DESCRIPTION OF A PROTOTYPE SYSTEM AND FEASIBILITY ANALYSIS)

Paperless accounting is creating all necessary informational premises for financial reporting with any reasonable periodicity [5], [6]. The only element missing for such frequent reporting to become implemented is a new block in already existing Internet-connected infrastructure shown on Fig. 1 – an electronic clearing house.

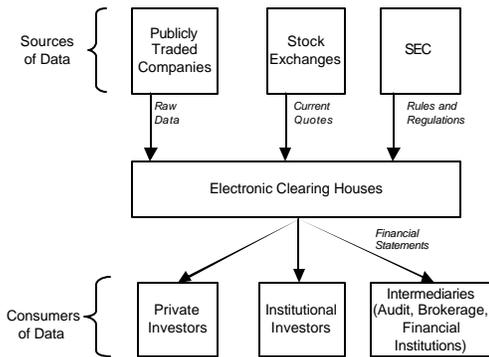


Figure1. Electronic clearing houses as a new element of an existing financial reporting system

The main mission of an electronic clearing house is clear from the block-scheme on Fig. 1 – to serve as a liaison between sources of data (companies, exchanges, SEC) and consumers of data (investors and intermediaries). This mission is to be accomplished by issuing financial statements with a periodicity desirable by each particular client. In particular, the clearinghouse would send emails informing registered shareholders that their companies' reports were posted or just email the financial reports and the supplemental information. This way every shareholder, small or large, will have an equal opportunity to review financial reports as soon as they are released.

Figure 2 - Flowchart of Functioning for Web Based Financial Reporting Using Clearinghouse - illustrates this approach. Operational applications (such as Sales or Manufacturing) generate, as a byproduct of

their basic operational functions, the resulting accounting journal entries, which, in turn, are fed into the general ledger system. It is feasible to create weekly or monthly financial statements from such an updated ledger (short of some additional entries) and submit them electronically to a clearinghouse. Shareholders of a corporation and other investors would have prompt access to these reports and financial ratios on an as-needed basis to facilitate the investment decisions. Obviously, a proper method to assure accuracy and the integrity of data must be in place.

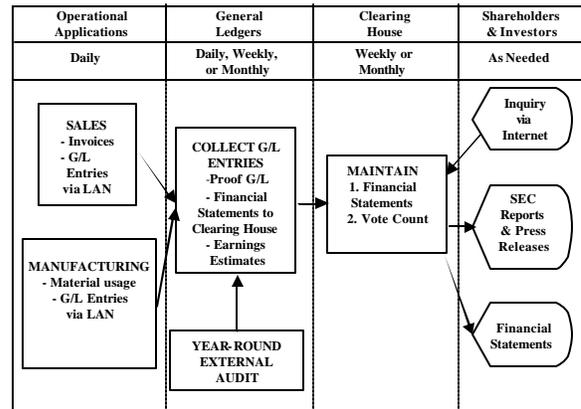


Figure 2. Web Based Financial Reporting Using Clearinghouse

For several companies, such as Bankers Trust of New York, the creation of accounting data is a required part of their technological architecture for each application. Therefore, general ledgers are customarily updated on a daily or weekly basis via magnetic media. Motorola, a \$22 billion company with six operating sectors, does its monthly books within 2 days; this proves that the preparation of frequent financial statements is an achievable task [7].

The existing frequency of report issuance (annually for audited reports and quarterly for the non-audited ones) was established in the pre-computer era. Corporations are now operationally able to prepare monthly or weekly reports and to issue them with much shorter delays than is done presently. Part of the delays is due to the usage of printer services preparing glossy reports, attractive to read, but taking a long time to validate and print. And with today's color printers and graphical capabilities investors may

receive quite esthetically pleasing reports via the internet.

Investors, both institutional and individual, would benefit from having these reports on a monthly or weekly basis. For this frequency change to occur, one or a few clearinghouses should be established in order to collect the reports from corporations and distribute them via the Internet.

Markets respond quickly to the reported news about earnings and earning projections of companies. Presently such information is known mostly to some financial analysts and institutional investors, thus depriving individual shareholders from using this information for their trading decisions.

Information submitted to clearing houses on a predetermined period basis should be accessible to all interested parties. The files should be protected from alteration. No addition or modification should be permitted, to assure the data integrity. Each shareholder would be in a position to retrieve the financial reports on his/her computer as soon as they become available at the clearinghouse or have them automatically emailed to his/her computer. Shareholders should still have an option of receiving paper printed statements, incurring the delays associated with their printing and postal delivery.

Some specific features of the electronic clearing house functioning are discussed in next paragraphs.

#### 4. SYSTEM DESIGN CONSIDERATIONS

The clearing house will receive financial statements from corporations as well as other statements and announcements (such as press releases). This information will be placed in a database. The clearing house will also maintain a list of all shareholders, with pointers to corporation(s) they own stocks in. The shareholder list will contain, in addition to their postal addresses, also email addresses. The financial data will be encoded in a way that will detect any alterations.

Upon receipt of a new report the system will automatically generate emails, including a hyper link, to all shareholders, enabling them to extract the desired reports from the

site. If a corporation has submitted its data in an Extensible Business Reporting Language (XBRL) then the reports will be transmitted in such a format to the users. Shareholders lacking email address will receive a hard copy report. The site will have the same way of navigation for all corporations, making it easier for users to obtain information. Furthermore, the clearing house will compute financial ratios for each corporation and their industries, enabling users to perform financial analysis. Obviously, shareholders will be in a position to access the corporate reports at any time, not only upon receipt of an email.

#### 5. FINANCIAL RATIOS AND VOTING

The financial statements should contain a comparison of several comparable periods for at least five years. Additionally, ratios comparing a given corporation to other entities within the industry group could be calculated. Such data should be helpful in performing financial analysis, including the computation of popular ratios.

In addition to the financial report, the corporations would transmit their SEC reports (10K, 10Q and others), their press releases, and disclosures made to financial analysts to the clearinghouse. Although SEC has a site, EDGAR, which contains SEC filings, it is difficult for a shareholder to navigate this site and the data is not arranged in a comparative fashion, which would help in analysis, especially for a small shareholder owning a dozen or two different stocks.

Since financial analysis is presently not required under the existing accounting standards, the users do not expect the issuer of the statements to perform a financial analysis of its own results. However, it would be advisable to request that the clearinghouse compute the popular financial ratios and indicators, without any commentary or recommendations regarding these results. This way an individual shareholder would have access to analysis available to institutional investors employing their own analysts.

The voting for the board of directors by all shareholders is done via mail. It could be done via Internet, assuming adequate security measures are taken. Several corporations are already offering such an

option, but again, having a standardized and secure procedure in one place would be welcomed by shareholders and it could even increase the voters' participation.

#### 6. XBRL- THE NEW LANGUAGE OF ACCOUNTING AND FINANCE (AN EVALUATION [8])

Users of accounting and financial information encounter many difficulties in transmission, reporting, quantitative analysis, and rewrites of accounting data. To relieve these problems the American Institute of Certified Public Accountants (AICPA), Reuters, and thirty other organizations organized, in year 2000, a task force to create the accounting-oriented new language, named eXtensible Business Reporting Language (XBRL) [9]. This language uses data tags or markers to define and describe data elements contained within financial statements. These markers, always attached to the data elements, permit users to utilize all data elements for variety of reports and calculations, regardless of the temporary position of such elements due to the sorting or processing of the data. Imagine an eagle with an implanted chip, which may always be identified, even if he moved to another location. Every language and software program, such as Java, spreadsheet, or data base language could identify a particular data element, such as a depreciation amount, based on the embedded marker. XBRL is still undergoing changes and improvements, but several companies and institutions are experimenting with the new language [10], [11].

The majority of users consider XBRL as having great potential for electronic data capture. It is important that any electronic data capture option offers a strong value proposition for the provider, especially when the provider is in regular and/or multiple collections. The value proposition is much stronger to deal electronically with us if the information can be extracted from their finance and/or other management information systems. The XBRL business case for providers is that important financial information is repackaged/reused for multiple purposes. Over the years, a number of different mechanisms for exchanging data

have been developed. These mechanisms tended to be proprietary or unique to the application or purpose for which each was created. XBRL uses the meta-language XML to define the XBRL document types and constitutes one of the many industry specific 'languages' of XML. XBRL, hailed as 'the digital language of business', facilitates the reuse of information contained in business reports, providing structure and context for that information. Leaders in the accounting profession such as the International Accounting Standards Committee (IASC) have researched the impact of the Internet on the distribution of financial information and have reached the conclusion that XBRL, or something similar, is needed.

XBRL can be viewed as a framework of 'controlled flexibility'. XBRL provides a method of creating 'name/value pairs' or 'mapping' which provides fundamental attributes about a value such as its data type, format, etc. XBRL provides agreement on the names but organizations provide different values within this framework. XBRL does constrain how you do things: XBRL provides 'name/value pairs' for expressing financial facts, but defines no financial facts;

XBRL provides a method of expressing lists of financial facts, the taxonomy; and XBRL provides a method of making values of financial facts available in an instant document.

XBRL provides the fundamental building blocks; users of XBRL do the building. Users define the facts they wish to exchange and build documents to exchange those facts based on what they need. The 'how' you must do it offers the predictability. Vertical integration, in terms of the use of a common set of standards between national providers and all of the international users of this information, is an important first step. It is to be hoped that the logical next step can also be taken and those same standards can be incorporated into provider accounting systems, making reporting a standard extraction. This outcome provides significant gains to all parties. We believe that if we are collecting information that organizations are also providing to ratings agencies, to stock exchanges, and to tax authorities, then the information will be much more accurate. At the same time, the organizations will benefit

because they have cut down on repetitive manual effort. Furthermore, XBRL utilizes templates that recognize the internal structure of financial statements, helping in the creation and quantitative analysis of such reports. Having the markers and templates, we will recognize a given amount, let's say depreciation, as a sale or administrative expense and also link it to the accumulated depreciation on the balance sheet. For users and preparers of financial reports it will be relatively easy to utilize such marked data for analysis, computation, reporting, and comparison with prior periods or other companies. It could be beneficial if the data in the clearinghouse is stored in the XBRL format, making it easier to utilize the data by different programs on different operating system platforms. XBRL is not limited to American users, but it is intended for use internationally. This way, it may also help by making the data of different countries more understandable to foreign users.

#### *7. COST AND SECURITY ISSUES ASSOCIATED WITH REPORT DISTRIBUTION*

The electronic distribution cost would probably not exceed the recent expenses of printing and distribution of paper reports. Most probably, it would result in significant savings. The cost associated with electronic reporting should be absorbed by the issuers of financial statements.

In addition to the distribution of financial reports, the clearinghouse should also distribute the ad-hoc company press releases to make them available to all users at once, as required by the new SEC regulations. The clearinghouse may also collect shareholder votes in board of directors elections, saving again on the mailing of proxy and the count of votes.

To make it easier for shareholders, every clearinghouse, assuming there will be a few of them, will automatically transfer reports of any corporation, even if it is posted on a different clearinghouse. This way no shareholder will be required to access more than one clearinghouse in order to get all his/her reports. In fact, it does not matter how a clearinghouse stores the data internally – it is only important that shareholders can base their

communications on standardized XBRL. The clearing house would have to undergo periodic audits by a regulatory agency, such as SEC, to insure that its operations satisfy the requirements for data integrity and secure accessibility.

Security of data transfer (tamper-proof qualities of the system) will not constitute a new problem and have been addressed by several sources [12], [13].

#### *8. NEW ATTESTATION STANDARDS*

Since corporations are not presently required to issue monthly or weekly statements, the auditing standards would probably have to be modified to take into account the new frequency and delivery methods. Issuers of financial statements would have to make more frequent adjusting entries, such as depreciation. However, these adjustments will not constitute a great hardship to the preparers since extracting this information from the existing computerized databases is easy.

The existing auditing methods would have to be modified, to provide for the attestation of issued statements. However, many auditing firms already perform "constant" audits of a company's results by examining its computerized records. In fact, some auditors have an online access to the computerized records of the audited company.

Most probably a new type of attestation opinion would have to be established for these frequent reports.

#### *9. PROPOSED STEPS FOR IMPLEMENTATION*

The above changes require time and careful planning for their implementation. The initial steps, foreseen for the change, are as follows:

- Issuance of standards for the new reporting frequency and attestation could take affect within two years, so the issuers would have sufficient time for implementation of the change.

- Execution of a pilot program for companies that will elect to comply with the new requirements before the due date.

- Selection of several clearinghouses to provide the distribution services. Each of the selected clearinghouses will be obligated

to transfer information about any corporation even if it is stored on another site. This process will be transparent to the shareholders.

-After an initial test phase all corporations will have an obligation to submit their data to a clearinghouse.

-Each shareholder will have an option to select the method of receiving the data about the corporation that he/she owes shares in. Shareholders will specify the desired delivery method: email, internet access on demand, or hard copy reports.

### 10. CONCLUSION

In conclusion, it is reasonable to assume that it would be both possible and beneficial, especially for individual investors, to receive more frequent, electronically distributed financial statements. The new technology makes such an operation possible, likely without any increase in the costs of delivery to the provider or user. Although some companies already offer such an option to their shareholders, these services would be more reliable and much easier to use if an independent and a well secured clearinghouse was responsible for the distribution of all financial reports.

Also, it would be much simpler for an investor holding several stocks to obtain information about all of his/her companies from one source in a uniform manner, common to all companies. The clearinghouse would be in a good position to ascertain that all reports are provided in the XBRL format, enabling users to prepare their own reports and analytical ratios, if so desired.

Shareholders would have to deal with only one source for electronic voting for their boards and have an instant access to companies' press releases.

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# Broadband Infrastructure and Rural Regional Development in Norway

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**Abstract—***This paper reports on findings of two surveys conducted in April 2001 and November 2002 on broadband infrastructure deployment and utilization of ICT services in 38 local governments of one county in Norway. Services include internal administrative services for the employees and services to the residents of the communities. We examine how well actual adoption of services had met with expectations. Findings show adoption and use was not as pervasive as expected. Our study is compared to several other regional area studies carried out in Spain. We conclude this can be an inhibitor to this area's regional economic development.*

**Index Terms—** *Internet and society, infrastructure deployment, public sector, business, and education.*

## 1. INTRODUCTION

The target of information technology strategies by regional policy makers, such as the EU Information Society, has been to provide access to infrastructures for public services such as e-government, e-learning, e-health services, and even to provide for a more dynamic e-business environment [5],[6]. Access to broadband (BB) networks is often seen as the enabler of such services [3],[7],[8]. The service infrastructures are also seen as playing an important role in maintaining a level playing field for regional economic development between rural and urban areas. One reason is that it is presumed that Information Communication Technology (ICT) can help

businesses to operate more decentralized, although urban areas have an advantage in attracting specialized knowledge workers and in becoming centers for development of new services and products. Another reason is that by utilizing ICT a social cohesion can be created among the participants, which reduce the effect of limited regional social networks of partners, suppliers, and customers. It is believed that regional governments can play an important role in promoting the use of ICT to create such social networks. OECD studies have shown that investments in knowledge resources such as education, R&D, in addition to capital investments in infrastructure are related to the development of innovative capabilities [15]. Local government's actions can help support innovation and demand in BB markets.

The Norwegian government's strategy for development of BB networks is demand driven. It is believed that demand for BB services will raise a competition among telecommunication providers to build BB networks and that this will give BB network access to virtually everyone [7]. In order to increase the demand, particularly in rural areas, the government has supported regional and local governments with partial funding for buying BB services. Public investments therefore play a vital role in creating demand for BB services in Norway. However, as economic resources from the government cover only a fraction of the total cost for the communities, local governments are also encouraged to co-operate with the private sector to strengthen the demand side.

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## 2. THE COUNTY OF MORE & ROMSDAL IN NORWAY

Møre & Romsdal (M&R) regional industries include fishing, fish farming, ship building, furniture manufacturing, mechanical industry and engineering and services related to the oil industry. 84.3% of 8000 registered businesses in M&R have less than 10 employees [18]. These industries operate within international competitive markets, where ICT is an enabler of operations. In 2001 the county was the second largest export county in Norway, with an annual export value of 2.8 billion € [18]. M&R has a total population of 244 000 in 15 000 sq. km. giving an average of 16 persons per sq. km. The county has three urban centers: Ålesund, Molde and Kristiansund with 39000, 24000 and 17000 inhabitants respectively. The geography of the county is mountainous with many fjords. Ferries are therefore an important part of the transport infrastructure, which is a challenge for transport and travel.

The County Department of Industry and Environment (IE) in M& R have considered how it can help to create a better economic development in its region. IE conducted a study to inventory assets and to consider the implication of investment elements. The OECD reports that Norway has lagged behind in knowledge based innovation [18]. Recent national policy has redirected funding in R&D to create centers of excellence to act as clusters of knowledge in specialized fields and to attract knowledge workers to Norway [16]. However, none of these centers are located in M&R, further pressing IE to support BB infrastructure development in the region. The national government supports the establishment and operation of incubators to strengthen innovation and research based commercialization in the country. While M&R County will benefit from recent national policies, it is also necessary to consider how local policies and investment decisions in ICT impact regional business development.

## 3. RESEARCH OBJECTIVE AND METHOD

One objective of this project was to find out whether the BB strategy put forward by the national government works well in rural regions. The eNorway plan states the national governments goal is that all community administrations, schools and community libraries shall have offers for BB connectivity at competitive prices within 2005 [7]. Several reports say that the community administration role shall be central as a natural information channel to the citizens and that they are responsible for effective interaction with the citizens [3,7]. Another objective was to find if local government expectations were fulfilled.

In mid 2001 a survey was sent to 38 local government administrations [13]. The objective was to assess these organizations need for BB networks, current satisfaction with network capacity, future plans for access and proposed use. A response rate of 45% (17 of 38) of municipal governments was realized. A follow up survey was sent in November 2002 to the 38 municipalities to see how far adoption and use of BB networks had come. We pursued and received a 92% response rate on the second survey [14]<sup>3</sup>.

## 4. FINDINGS AND COMPARISONS

Although many factors contribute to the integration of ICT in regions, in terms of regional development and use of ICT in innovation, we concentrated on the following factors: i) availability of infrastructure, ii) the types of public service units with BB access, and iii) the applications of ICT in use by the communities. These factors have also been examined by other studies and in particular the Andalucía region of Spain [1] and the Madrid region of Spain [9]. Our study points out some important similarities and differences between these regions and ours. Comparative case studies often have difficulties in establishing general findings. We argue the value of our study is to point out our areas unique perspective and its

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<sup>3</sup> A follow up telephone survey was made in September 2004 to check on the current status. 94.7% (36) communities now have BB access. But only 79% (30) of them have access rates over 2Mbps.

special set of circumstances. In essence, one generalized model would not provide a good basis for the effective development of BB in all rural areas.

#### A. Infrastructures

Developing high bandwidth infrastructures are high cost undertakings. Population density and business density in a region are important factors to consider when investment decisions in BB infrastructure are taken. We remind, the population of M&R is 244000 with 33% living in the 3 towns and 84.3% of businesses in M&R have less than 10 employees. In our 2002 study, 60% of the communities in M&R claimed BB access. But, some had multiple access types. These percentages are in Table 1. Percentages for 2001 are from [13], (p.45). The selection of access technology was evenly distributed over the technologies types of wireless radio, xDSL technologies and fiber. In many communities there was a combination of adopted technologies. Fiber cable, with access speed of 2Mbps or greater was the most used. The evidence indicates that ADSL is the most dominant of the DSL technologies.

We compare our region with two regions in Spain. One study compares ADSL deployment to cable deployment in the Spanish region, the Community of Madrid, made up of 179 municipalities [9]. They found prior to April 2001 that ADSL and cable were available coincidentally in the same regions. But, since that time the expansion of ADSL had extended to 111 of the 179 municipalities, while the cable coverage was available in almost the same municipalities as before. They found not one municipality of 19 with less than 250 inhabitants/km<sup>2</sup> had ADSL, while all of the 82 municipalities with over 2500 inh/km<sup>2</sup> had coverage<sup>4</sup> [9]. All of these regions have a higher population density than M&R.

In the southern Andalucía region of Spain they have 3,064 businesses in just the ICT sector, with 96.1% with less than 10 workers. They have a regional population of 7.2 million with 43% of the population living

<sup>4</sup> Ratio of %Penetration -to- #inhabitants/km<sup>2</sup> was .00:<250; .06:>250; .26:>500; .30:>1000; .50:>1500; 1.0:>2500. [Source:9]

in cities and 32% concentrated in the provincial capital. The Andalucía noted a large difference between urban and rural access to high bandwidth infrastructures. In particular, they estimated that only 3% of the regional population had access to cable networks and 14% of the households have access to ADSL [2].

#### B. Institutional units with broadband access

We next examined which institutional units within our communities in M&R had BB access. We note that another study done by ECON Analysis [4] examined institutional access by technology type for Norway in general. If we sum the technology access types from their report (DSL, fiber, radio, and other) we see Norway in July 2003 reported national percentages: central administrations (49%), libraries (43%) and ground schools (34%) in ECON Analysis, page 32 [4]. It was anticipated in a February 2003 study that penetration would be 74%<sup>5</sup>, 63% and 45% respectively by 2004 [17]. In our study, in M&R, we find that central administration, primary schools and health care organizations are more likely to have

TABLE 1  
M&R NETWORK ACCESS TECHNOLOGY

Technology municipalities with->	% in 4/2001	% in 11/2002
Wireless radio	12	31
ADSL /SDSL / VDSL	6	31
Fiber	24	40
Coaxial cable network (i.e. cable TV network)	6	6

BB access than other institutional units. We claim that the M&R communities may see education and health care as representing a major proportion of community services as they were in November 2002 at the 2003 access level. Last, ICT operation and management functions in these units are often managed by the central administrations. So, it is natural for central administration to lead in connectivity.

Table 2 shows the percentage of the municipalities that has one or more of its service units assigned to a BB network. For example 48% have a central administration

<sup>5</sup> See footnote 1.

with BB access, and 51% have at least one primary school with BB access<sup>6</sup>. In addition to the local institutions mentioned above, the county has 26 junior high schools and 4 hospitals which all have BB access. We find a significant difference between the 3 urban municipalities and the remaining 35 rural municipalities. As noted earlier, our urban areas are considered low population areas by EU standards. Table 2 shows that all departments in the urban communities are connected to BB, whereas the rural communities have less thorough coverage. About 40% of the rural municipalities “primary services” (health care, schools, and central administration) are connected to BB. The difference between rural and urban areas is even greater for schools. All primary schools in all urban municipalities have BB access, whereas some schools (at least one) in 45% of the rural municipalities have BB access. The fact that urban communities have come longer in the penetration of BB networks is a general tendency in BB deployment. Higher density areas represent bigger demand and are developed first.

In the Andalusian report they characterize the type of users in the region to demonstrate that this is a factor in the usage and adoption of ICT. In particular they state, “The lower level of education in general, and knowledge of languages in particular, of the Andalusian population, and the traditionally lower level of income per capita limit the capacity of citizens to access these (ICT) technologies.” [2] This is not however the case for M&R. The population across Norway is rather homogeneous in educational opportunities and households have small deviations in average income. While persons in rural areas have on average, fewer years of education than urban areas, the knowledge of foreign languages is reasonably good. Norwegians receive formal education in English from an early age. Along with the other Scandinavian countries Norway has a very high penetration of PC’s and availability of internet access. 74% of persons over 13 year have access to internet [10]. The

national average in Spain is 23.4% of persons over 14 years have internet access and the average in the Andalucía region is below that at 18.2% as measured in 2001 [2]. The Andalucía region also has the largest percentage of young people in Spain. Those younger than 15 years represent 23% of the regions population, as compared to the national average of 19.4%.

TABLE 2  
ORGANIZATIONAL UNITS WITH BROADBAND ACCESS

BROADBAND USERS	% OF MUNICIPALITIES		
	ALL	URBAN	RURAL
CENTRAL ADMIN.	48	100	41
PRIMARY SCHOOLS	51	100	45
HEALTHCARE INST.	45	100	39
PRESCHOOLS	20	100	16
CULTURAL INST. (LIBRARY, MOVIE)	31	100	26
OTHER INSTITUTIONS	8	33	7

This region therefore looks forward to larger growth of internet users in the next 10 years.

Other demographic conditions, such as geography of the M&R region, M&R regional distance from central Europe and the high cost of transportation internally and externally, are likely to be more significant factors in encouraging M&R users to adopt the use of ICT than they are in Andalucía. At the same time, we recognize that adoption and use of ICT by community administrations require education and training.

As an inhibitor to this, rural communities may have access to less resourceful “knowledge networks.” The regions businesses and the experiences of their knowledge workers are contributors to the richness of these networks.

<sup>6</sup> Most communities have all schools connected to one internal network. We did not have information on the number of schools per community that had access.

C. Applications and services

The electronic network applications or services that dominate are i) general information searching, ii) presentation of

TABLE 3

Applications	% of municipalities	
	Use at all (2-5)	Much use (4-5)
Information searching on the Internet	91	47
Presentation of community information on the web	100	26
Communication with external contacts by e-mail	85	56
Education of employees	29	3
Network meetings as a substitute for travel	0	0
Purchasing via public electronic marketplaces	50	9
Electronic invoicing, either sending or receiving	6	6

community information on web sites and iii) the use of e-mail for both internal and external communications. These services do not require BB capacity. However, the ECON analysis [4] has classified BB services requiring the following minimal upstream and downstream bandwidths: Internet web browsing (64kbs, 64kbs), E-mail (64kbs, 64kbs), File transfers (128kbs, 128kbs), Video conferencing (256kbs, 256kbs), Video-on-demand with MPEG-4 (64kbs, 500kbs). However, these bandwidths are for minimal functionality. These services do not fully represent the full range of usage. For example, health workers may need to connect to central databases from mobile technologies such laptops or telephones while on calls to patients. Institutions with greater demand for existing services and with the creation of new services will have a greater need for BB access.

As another example of the nature and complexity of services is the central administrations access to its citizens. Today all M&R communities have a web site that contain, or provide links to, relevant information about the community. At present there is a large variation in the quality of community web sites and many

communities have a considerable potential to improve their sites. Nevertheless, the website has become an important communication channel for the municipalities. For example, these community web sites often act as portals into private services of the region, such as helping people find health services, jobs, places to live, travel information, deadlines for applications, and much more.

In this study, we asked the M&R respondents to grade the usage of the services from 1 to 5, where 1 means not at all and 5 means very much. In Table 3 the results are grouped into communities with some use at all (answer is different from 1), and communities with much use (answer is 4 or 5). In Table 4 we again see a substantial difference in the use of applications between urban and rural communities. Urban communities have come further in usage of services such as purchasing, invoicing and to some degree in education, such as training employees through e-learning. Much of this difference

TABLE 4  
ELECTRONIC NETWORK APPLICATIONS, RURAL AND URBAN MUNICIPALITIES

Applications	% rural municipalities		% urban municipalities	
	Use at all (2-5)	Much use (4-5)	Use at all (2-5)	Much use (4-5)
Information searching	90	42	100	100
Presentation of information	100	23	100	67
Communication by e-mail	84	55	100	67
Education of employees	22	3	100	0
Network meetings	0	0	0	0
Purchasing emarket place	45	3	100	67
Electronic invoicing	0	0	67	67

may be explained by the fact that the urban communities are the early adopters and are supposed to have achieved a higher competence and expertise to make use of

more advanced network services. In addition, since urban communities have larger administrations and larger volumes of information transactions (such as invoices, etc.) they can achieve higher savings by utilizing the services listed in Table 4, than those in rural communities. One service that has not been stated to be used in the M&R region at present is video-conferencing for network meetings. Despite that nearly 35% of the respondents from the 2001 investigation said that this was an application they would use, it has not yet been adopted by the municipalities. This is surprising in that the urban communities are using networks for education, it can be expected that two-way video conferencing would supplement this process. Part of the reason may be that end-user equipment for video-conferencing still is rather costly and requires some user competence. It may also be that the current bandwidth is not sufficient to achieve the desired interaction quality. Finally, much implicit information can be lost in the use of video conferencing.

TABLE 5  
EXPECTED USE VERSUS ACTUAL USE FOR SOME BROADBAND APPLICATIONS

Applications	% of municipalities	
	Expected use	Actual use
Presentation of community information	100	100
Purchasing via electronic marketplaces	70	50
Education of employees	58	29
Network meetings	35	0

These systems are found to work best when an initial, in person, meeting is first established. On the other hand, if the need of communities is for a one time meeting with different participants every time, it may be that video technology is not a good substitute for the personal meeting [11].

The Andalusian observations of use of applications were similar to ours but they included businesses and used other measures. They stated that most companies did not go beyond searching and exchange of information. But, larger companies were more inclined to integrate ICT in B2B activities. They used an indicator to measure

the degree of implementation of electronic administration to be the number of terminals per 100 workers. In public administrations this was higher (52%) than for companies (42%). They noted several regional public programs that support the development of on-line public services, digital literacy and the development of digital content, have helped public administrations in their rural regions to adopt new technologies [1]. In our 2001 investigation which included businesses in the region, we did not make the same measure, but we noted a similar trend as public institutions were leading the adoption of BB access over private businesses.

#### D. Expected versus actual use

What services did the communities in M&R expect to use in 2001 and what services were actually used in November 2002? We make a comparison of the studies. As shown in Table 5, the expectations were higher than the realized usage.

In 2001 we did not ask the municipalities if they planned to use ICT for electronic invoicing, use of email, or searching for information on the web. So, we cannot compare expectations in these areas, however, we see that use in electronic invoicing was low. As shown in Table 5 use of advanced services like education of employees and network meetings was below expectations. Comparing with Table 3, only 9% (purchasing) and 3% (education) of the municipalities have reported to have made "much use" of these applications. Again, given the geography of M&R, some of these responses are surprising.

We find in M&R that for many communities a short term value of high bandwidth investments is overestimated and a long term value is underestimated. Policies in Spain reflect an attitude that high bandwidth content applications are not ready so middle bandwidth access is acceptable. While in M&R many municipalities had formal plans for BB access in 2001 and had achieved this 1.5 years later, as stated in Table 1, M&R municipal administrations have so far not fully utilized their ICT. Applications expected

to be used in 2001 have had low adoption and especially the advanced network applications receive little use. In particular this is the case for education (e-learning) and network meetings (video-conferences). But, it is wise for the municipalities of M&R to be patient and keep a long term view. In the Andalucía study they state that more than 73% of their public organizations have simple web page presentations on the Internet. Community needs like supporting tourism and access to community events are becoming more important to the economy of the communities. These needs from community participants will spur community administrations to make more use of their networks and increase their need for high bandwidth access.

#### 5. CONCLUSION

We conclude that a lapse of 1.5 years is too short of a period to observe great rates of change in the adoption and usage of BB in the M&R region. However since the count of national BB providers have increased, and penetration has increased, it is an indication that the national demand driven policy is working<sup>7</sup> [12].

One conclusion we make by comparing our region with the Andalucía region and the Madrid region is that our social-demographic barriers in M&R are much less and should manage the expansion of services with greater ease. Although the two Spanish regions are different in character that is Madrid is more urban and Andalucía is more rural, they are both under one national policy. The national support systems in Spain have seemed to make it easier for the adoption of ADSL technology. But, these regions have relatively large differences in population density between urban and rural areas in their regions. The urban areas are very concentrated and the rural areas are quite dispersed. To make the most of funds, they must concentrate resources on the urban areas leaving less for the rural area. In Norway, even the "urban" areas are considered "rural" by European standards. Also, in Norway, and in M&R in particular,

the differences in population densities are not so great between town and country. So, the dispersion of resources, and even the dispersion of demand for service is much more evenly distributed. This means that Norway should have a policy to more evenly support the same level of bandwidth access in both urban and rural regions.

While it has been our clear observation that most rural areas have eventually gained BB access, they did not gain access before the urban areas and there still are differences between rural and urban areas in M&R. What rural areas have achieved are somewhat hidden in the details. That is, it seems clear that many municipalities in rural regions are not able support their inhabitants electronically in the same way as urban municipalities can. For example, "24 hours" availability of some information services cannot be made available, or personnel attendance may still be required for certain services. As such, rural communities do not utilize the saving potential from effective use of ICT and cannot upgrade as quickly. The lesser demand of users in rural communities is often not great enough to justify the initial investments and improvements. National programs are still needed to support the lowest demand areas. This is supported by another national trend. That is since 2002 many institutions that had high bandwidth access already, have since upgraded to higher speeds. While those that have lower speed access have not sought upgrades [8]. Yet, as we have pointed out the value of present day applications cannot be fully realized at low bandwidths. Also, considering that many of tomorrow's BB services are not yet developed, it makes it difficult to estimate the impact on the rural communities' economies. The findings of this study indicate that the demand driven strategy for BB infrastructure development has some limitations, especially for rural areas. These limitations can be an inhibitor to regional economic development. be an inhibitor to regional economic development.

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# An Information Retrieving Service for Distance Learning

Lauro Nakayama, M. Rosa Vicari, and Helder Coelho

**Abstract—The Lifelong Learning environment has specific features and it is strongly supported by Information and Communication Technologies. Our idea consists of a web service to aid the student along the information retrieval and mining process. The service is supported by three different agents. The user profile, the student model and the intelligent information mining process. This information permits us to generate a refined search term according to the student's needs, which occurs during the solution of a problem. The main advantage of this service is a refined search result that can aid the student in his educational activities. This service composes the kernel of the Web educational portal – PortEdu.**

**Key words - Learning Environment, Web Semantic, Virtual Community**

## 1. INTRODUCTION

LIFELONG learning is crucial in preparing workers to compete in the global economy. Nevertheless, it is important for other reasons as well. By improving people's ability to function as members of their own communities, education and training increase social cohesion, reduce crime, and improve income distribution [20]. We assume that learning is the use and the creation of new operational knowledge [5] that steers our actions. Learning is a social activity in which interactions with the environment (human and artificial agents) play an important role.

Our proposal is a web service to aid the student along the information retrieval and mining process. The service is supported by three different agents. The first one is connected with the user profile, the second is the Student Model, and the third is the intelligent information mining process. This process is based on the student's cognitive information on the course subject and the general information about users preferences. This information permits us to generate a refined search term according to the student's needs, which occurs during the solution of a problem. The student can receive assistance in his educational activities with the refined search result, which is the main advantage of this service. The agents have the facility to design new valued-added tasks. This service composes the kernel of the Web educational portal – PortEdu – which covers several courses, chat, forum, registration and statistics facilities, just as several well-known distance learning environments have. At the moment PortEdu is being used by 60 regular medicine students in the cardiology area at UFRGS (the Federal University of Rio Grande do Sul). This experiment is the first test to be carried out. We believe serendipity with a new generation of inference engines will impel students to be more involved and active in education.

## 2. LEARNING ENVIRONMENT

Learning environments can be most any environment in which a person can learn (a traditional classroom, a distance course with occasional face to face meeting, a course on the Web, a learning community, learning at the job).

It should be possible to adapt the learning

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environment to certain characteristics on software interface, content, context and learning. For instance, an inexperienced learner will find difficulty compared to an experienced learner. If the student is an inexperienced learner, then the search result can be a more generic text. If the learner is well experienced, the search result can be a specific text or a particular image.

The content of the course will have specific characteristics. It might be useful to adapt the environment to the context in which it is used. It is possible to take into account such differences as computer literacy, background and cultural distinction. The learning environment should be available for all kinds of users. Therefore, when designing an environment, the context in which environment will be used (country, culture, availability of computers, subject area, type of learner, and experience in learning) should be considered.

#### E. THE PROBLEM

The exponential growth of the Web and online resources in general has brought forth a real problem: an overload of information on the web. This rapid growth makes it difficult to navigate on the Internet. The capacity to efficiently access what really is relevant for the user becomes crucial for the effective use of the Web, that is, the refinement of the search. In our system, the refinement is done automatically, based on available information in the users and students models (proactive personalization). The student does a high-level information request and receives a distilled reply.

Internet research requires a special ability due to the speed in which the page information is modified along with the diversity of involved people and observations [10]. Navigation needs good sense and intuition. Good sense in order to not be stymied before so many possibilities, knowing how to select what is most important in quick comparisons. Intuition is a radar that we are developing to click the mouse on links that will take us closer to what we are looking for. Intuition enables us to learn by repeated attempts; encountering rights and wrongs.

The focus in this work is to present an agent enabled to recover web information in an intelligent way [8]. The semantic web is intended to complement humans in areas in which they do not perform well, such as rapidly processing large volumes of information or analyzing large text. The proposed work, even with an intense motivation in the technological area, has the objective to verify if intelligent search mechanisms can efficiently collaborate with the students in their learning activities on the Web. The adapted pedagogical model in PortEdu is that of constructivism.

The agent model using the concepts of Piaget's Constructivist Theory, finds inspiration in the Genetic Algorithms model, in the Neural Network [7] and in the principle of The Society of Mind [11]. The previous models had already tested this combination, published in [3].

Knowledge assimilation and accommodation tend to become better and more integrated with the cognitive development. The agent has an interface with the environment (sensorial inputs and motor outputs) and some schemas (its cognitive constructions). Thus, the mechanism proposed is able to build its knowledge by interacting with the environment while it carries out its activity. A schema is composed of {*Context*, *Action*, and *Expectation*}. The *Context* is the representation of situations that the schema is able to assimilate. *Action* represents the action that the agent will carry out in the environment if the schema is activated. *Expectation* represents the expected result after the action application.

#### F. SOFTWARE AGENT SOLUTION

This work is based on the definition that an agent perceives its surroundings by the use of sensors and acts directly in the environment [15]. In order to bestow intelligence for consultation, two PortEdu agents will provide information to the Information Retrieving Agent: the agent that obtains the user profile making available search terms starting with information on students behavior when he interacts with his classmates and uses the Web;

and the Student Model Agent (educational application agent), which has information on the knowledge of each student concerning the pedagogical content at issue.

The User Profile Agent has two characteristics: reactivity and continuity. It is reactive because it perceives all the changes in the student's behavior as in his deportment once away from the foreseen activities in the learning application. That is, it perceives the actions done by the student in PortEdu. It is continuous due to its constant execution in the portal.

The Information Retrieving Agent is cognitive and proactive as it elaborates search plans starting with received information by the User Profile Agent and the students model. It acts when requested by the student or offers help to the student (a search result, for example) when activated by the students model. Figure 1 presents also the relationship between PortEdu and the web learning applications.

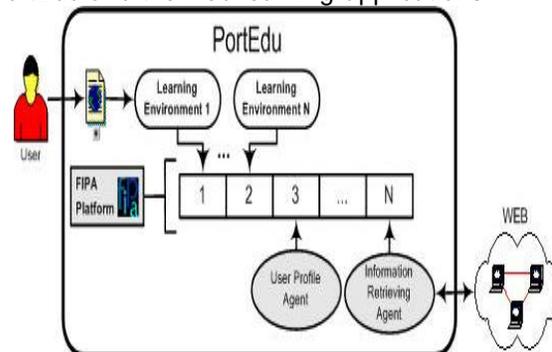


Figure 1 - PortEdu using the FIPA Platform

We propose an architecture using the FIPA (Foundation for Intelligent Physical Agents) platform [4] as a protocol of communication between agents for our environment. The communication among the agents and the learning environments will be based on the FIPA-OS (in the communication structure we use ACL - Agent Communication Language).

### 3. USER PROFILE AGENT

The creation of terms for intelligent search must consider the result to be obtained. In the case of this work, the intention is to aid the student during the use of the learning environment anchored to PortEdu. The aid

to the student will be carried out by the obtained contents through the intelligent search mechanism or the indication of a participant in the group that has the knowledge to help him out in the learning of a specific subject.

The information captured by the user profile is:

- Subject: when proposing a search, the information on the context of the student's work is fundamental so that the retrieved document may be useful in the solution context for the student's problem.
- Cognitive context: the Information Retrieving Agent needs to know at what point of the content the student is specifically working on so that it is possible to specify and refine the search. We use a Probabilistic Multi-Agent Environment [19] to test our Information Retrieving Agent. The IT (Intelligent Tutor) is an educational application where the content and the student model are implemented using Bayesian nets. The user profile needs information about the Bayesian net variable where the student is working (solving a particular problem) and about the variable probability information, in order to do a particular search (see Figure 2). These two terms that were obtained from the students model make the difference between the retrieving information process described here and the mentioned techniques in this paper;
- Ontology: The ontology will define which is the best type of content that should be retrieved in each variable. Each educational application could have their proper ontology. An ontology formally defines relations among terms, that in this work has a set of inference rules;
- URL: the User Profile Agent makes available the URL's for the information retrieving agent that were used by other users;
- User history: the User Profile Agent must supply the Information Retrieving Agent the user history related with the chosen web subject. This history is carried out based on the already solved problems by the user in his previous knowledge on the subject, etc.;



We may observe that the user profile will be updated at all times (profile will be dynamic). Thus, there is the intention to obtain a closer modeling to that which represents the user at his last instant in the environment and not only a historical profile (some users along the way may change characteristics in their profile).

As a related work, we can mention in [14], which is an adaptive front-end to Google. This work limits itself to model the user's preference during use in the Google portal, not worrying with other aspects of the user. Behavior aspects are understood as the user's developed activities during the navigation in the environment. Another work in this context is *Generic Architecture for User Modeling* [18], who defines the user behavior model in the Internet by making use of an infra-structure (backbone), built on three heuristic levels, user interest, type of documents, and user behavior.

#### 4. INFORMATION RETRIEVING AGENT

Nowadays, there are many applications and prototypes of models based on intelligent agents, such as Search Advisor, Letizia, and InfoFinder. These systems have as an objective to assist in the consumption and organization of the available information on the Web [12]. These applications have the most varied purposes, making more searches from the informed terms by the student, up to accomplishing the personal preferences in learning of each user and, based on this, to bring about information searchers that attend to user .

In our solution the agent differs from the others due to the refined document selection. We compare the user interest profile with the retrieved document, convert the database that contains the examples of positive interest and the retrieved document in vectors where each element represents the weight of the terms in the document and the Student Model information. Calculated by the following method: Term Frequency X Inverse Document Frequency [16,17], we find the angle between one vector and another (see Figure 4). The smallest angle found is our quality judgment. The smaller the angle, the bigger the proximity of the document with the profile and expected

subject by the user [2]. Thus, we are using Salton & Chen's models enlarged with the attained information through the user profile and, the Bayesian network variable and probability.

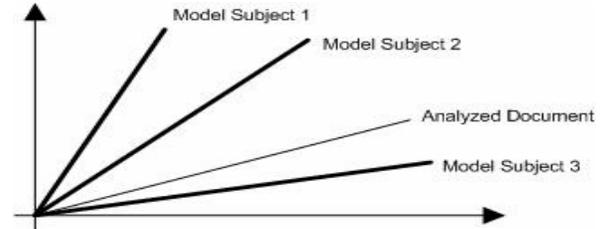


Figure 4 - Comparison between vectors

A vector is created for each retrieved document (model subject N). The analyzed document withholds the obtained information by the User Profile Agent and the information from the Bayesian net concerning the context of the problem that is being solved by the student.

Salton's method is used to calculate the frequency measurement of a word in the document. The weight of  $W_i$  of a  $d_i$  word [16], on a certain document is calculated by:

$$W_i = \left( 0,5 + 0,5 \frac{tf(i)}{tf_{max}} \right) \left( \log \frac{n}{df(i)} \right)$$

Where:

$tf(i)$  → is the frequency of the term  $i$  on the document  $t$ , that is, the number of times that the word  $d_i$  appears in the document;

$df(i)$  → is the frequency of the document, that is, the number of documents of the collection which contains the word  $d_i$ ;

$n$  → is the total number of documents in the collection;

$tf_{max}$  → is the maximum frequency of a word among all the words in the document.

Once the weight of each analyzed word of the document is obtained, each one is placed in the vector in the corresponding position of the word. The same happens to each set in positive interest models, linked to the subject, as we have both the weight vector for the analyzed document and a vector for each subject on the users interest [2]. The angle between the vectors is by the following formula [1]:

$$Angle = a * \cos \left( \frac{\sum (a_i * b_i)}{\sqrt{\sum (a_i)^2} * \sqrt{\sum (b_i)^2}} \right)$$

Where  $a$  represents the analyzed vector and  $b$  represents the vector of a subject of interest. The formula above is applied for each one of the vectors at matter, being that the lowest angle is put into use as it represents a height proximity between the subject and the analyzed document. Each process above will be repeated in the second stage, which is the final classification with information on the Bayesian net with significance level, weight and the probability of hits that will be informed by the User Profile Agent.

The use of attained information by the User Profile Agent, with the educational application in particular, permits to add links in a link repository, with integrity classification, and the judgment for the inclusion of reference in a repository or not. The classification of the document takes in accounts the students and expert (professors) comments. As the Information Retrieving Agent will be offering services in an educational environment, it can automatically retrieve information and offer the student the text content, image, sound and knowledge.

In our application, the navigational sensors will try to obtain the user interest profile and update the database concerning the subjects on user educational interest (User Profile Agent task). The InfoFinder also makes use of stored information in the database to generate consultation, which will be submitted to search (NetClue – Browser/Google), but the information stored by InfoFinder is generic. The attained results on previous searches are stored in a database of candidate addresses and will be selected by the link selector and submitted to the subject classifier to be stored in the link repository (organized by subject). The integrity and the confidence verifier has as its goal to access each one of the stored addresses in the repository to check if they are active and consistent, and in what rate of reliance they meet at the moment. This operation is necessary in the consulting return in order to better refine the search result and check the confidence of the documents.

The performers represent the encountered replies from the search agent

and are offered to the environment with the objective to alter the state of interaction between the student and the educational system that is being used. The Information Retrieving Agent is divided into four great functions:

Navigation: responsible for searching web information that satisfies the user interest profile and adds it to the list with the intention of being selected or not in the future in the repository;

Reach information from the student model: gets information on the cognitive state of the student. The information must be available in the application. This task is offered by the Information Retrieving Agent for the educational application;

Links selection: that chooses, by different discernment, which existing links in the list created by the InfoFinder will be effectively added to the definitive repository;

Subject classification: responsible for the classification by subject, of the selected information and insert them in an organized way in the repository.

Information confidence and integrity verifier: which should, from time to time (or when the user activates it) perform verification on all links stored in the repository with the intention to withdraw inconsistent and eventual out-dated links, or even what does not correspond to user profile. To aid in the links consistency, we will provide a scale with metrics to assist, as for instance, the concepts of academic links. The possibilities for the user, expert or student, to configure this scale as to his single needs (confidence on the extracted information in the repository) will be available.

As a related work we can mention the approach to automatically optimize the quality of retrieving the information in search mechanisms using navigational data [6]. Intuitively, a good information retrieving system should present considerable documents on top of ranking, maintaining the non-relevant documents in the sequence. The Search Adviser, Letizia, and InfoFinder, have in common the apprenticeship of the general profile of the documents. This apprenticeship is done by the use of heuristics and extracts sentences

that are representatives of the main topics on each document [9].

Next is an example of message content from the User Profile Agent to the Information Retrieving Agent within PortEdu that will be used for the development of the search term.

```

<search term>
  <user>miletto</user>
  <Subject> Cardiology </Subject>
  <Category> congenital heart disease
</Category>
  <Excluder Node>
  <Description> Rheumatic Fever
</Description>

<Issue>Autoimmune, Systemic</Excluder Node>
<User Preferences>
  <Language> Portuguese, English
</Language>
  <File Type>
    PDF, DOC, HTM, TXT, JPG, BIN
  </File Type>
  <Bandwidth> Broadband </Bandwidth>
</User Preferences>
  <User Knowledge> ? </User Knowledge>
  <URL>http://educacao.cardiol.br/accsap/answers%20comentadas%2003.pdf
</URL>
</search term>

```

The example above was made using cardiology terms as a pedagogical context. The message content from the User Profile Agent to the Information Retrieving Agent is based on XML architecture. The message above will be dealt with by the Information Retrieving Agent that will bring up a specific search term for the chosen search tool. In recovering the information, the Information Retrieving Agent filters and classifies the results based on the information contained in the message search term and the ontology at the learning environment at issue. Making use of the message search term example shown above and the standard Google search tool, the Information Retrieving Agent develops the following specific search term: Cardiology + "congenital heart disease" + "rheumatic fever". This term is submitted to Google retrieving 10 result pages. The next step is

to make the classification and the percolation result based on users preference and the ontology, reducing radically the quantity of resulting links, increasing the level of relevance. The user preference is: Portuguese language and TXT type document. This refined classification is a cognitive context, in which the student is working or needing assistance. This would result in a well-reduced research with two URL's at the most. Before launching a search, the User Profile Agent certifies if another participant in the group had already requested it. If this occurred, the User Profile Agent notifies the application about the fact that a student has already come up with the same demand and that he could aid the present student in his learning process.

On the other hand, a test was performed on Google with the same subject above, considering the statistics in which a user makes use of two terms at the most in a search mechanism. This way the user would use the term cardiology; cardiopathy, retrieving 210 pages in different contexts from those of interest.

Once the filter and link classification is done, the Information Retrieving Agent communicates to the learning environment that there is available content to complement the information on the topic in which the student is working on and makes available URLs with content, used by other students with similar problems. The precise moment to present this content to the student is determined by the set of learning environment agents, as it depends on the pedagogical model.

Once it is decided by the learning environment agents to deliver the retrieved content to the student, it is necessary to find out if this content was effective in the learning process. In this phase we are working on a good quantity of sections, time-interval, and the importance of the retrieving information (utility weight of the document obtained from the expert and student) for knowledge development. To increase the level of efficiency in future searches, links and contents are stored in a link repository, considering the weight and the comments made by the expert and students.

## 5. FINAL CONSIDERATIONS

The Information Retrieving Agent is now in a test stage using Google integrated on PortEdu. The automatic content retrieving information process, based on user profile information and student model knowledge, is the differential of the traditional search mechanism. The initial tests show that the contextualized search process can really aid the student. For instance, the bigger the significance of the node at matter, in the building of the net, the smaller the number of retrieved documents and these tend to attain significant information for the solution of the problem. The bigger the number of variables (nodes) is obtained in the Bayesian net, the better and more significant is the retrieved documents quality. In our example we are using over two levels (parent nodes) of the conflicting node. Thus, the availability of the intelligent retrieving information process, the main goal of this work, brings a qualified contribution. That is, different from most available search agents, as mentioned before, its functions seek to attend specific Lifelong Learning environment users.

The main difficulties in this project are to anchor technologies and put them together with an operator. The project integrated a variety of previous work developed by the group. This integration was facilitated by the adoption of the FIPA communication platform. The use of software agents engineering techniques permitted the integration of several different software components. The use of the same communication language must be considered.

The initial results that we have obtained with the retrieving information, contextualized and personalized, are encouraged and permit us to believe that this research will be important for learning environments on the Web.

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# Towards a methodology for evaluating the quality of (public) websites

Cornelia Neuner and Christ'I De Landtsheer

**Abstract**—*Creating a successful website is not easy. This is an obvious conclusion when looking at sites that are difficult to navigate, find information from or interact with. As users, we are struggling with poorly designed and implemented sites. As researchers, we need to tackle the problem in a new way. It is important to understand that it is not enough to make a website functional but also usable, appealing, compelling and engaging from a user's point of view. The 'art' of creating engaging websites needs new interdisciplinary approaches presenting perspectives from communication studies, film and media analysis, graphic design, architecture, development of digital technologies and computer science, etc. as well as a psychological understanding of the human being as an emotive, sensuous, cultural, intellectual and social being.*

**Index Terms**—*framework, technologies, websites.*

## 1. INTRODUCTION

This paper argues that the current methodologies applied to evaluate the quality of websites are too limited. We need a changed view of literacy, since websites are an inherently visual medium and enable us to combine text, images, audio and video in an innovative way. Moreover, the borders between authors and the audience as well as between reading and writing/designing are blurring. People can add and manipulate the content by themselves and decide which parts of the content they will see hear and read or not. Instead of being pure 'receivers'

of information they can become communicators, designers and authors. Moreover, for the creation of useful and engaging public websites it is important to put the citizens in the center of the site design to meet their needs and desires.

An in-depth debate about the concept of the public sphere is beyond the scope of this paper. Nevertheless, the shaping of Europe and other areas of the world highly depends on media – increasingly also on new media like websites – and communication. As media and communication change, so does the concept of the public sphere - in a political, social, economic and cultural sense (Weinberger, 2002, Burnett & Marshall, 2003).

This paper will first provide a brief overview of current literature, and reveal the limitations of existing frameworks evaluating the quality of websites. As a further step we will explain the need for a new and more integrated framework as we have already roughly developed in earlier studies (De Landtsheer, Krasnoboka, and Neuner, 1999, 2001, 2004)<sup>2</sup>. Finally, we will suggest some initial steps in this direction and draw our conclusions.

## 2. WEBSITES, TECHNOLOGIES, AND COMMUNICATION

The analysis of websites is a recent area of study, nevertheless there is a growing body of research focusing on the development and measurement of website content. Unfortunately, most of them do not look beyond the scope of their discipline and are only paying attention to selected features of websites without providing an overall picture.

A website is not simply displaying information electronically.

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The GUI (graphical user interface) is a mediator between the human (cognitive system) and the technical, social and medial environment. It mediates and enables new forms of communication (one-to-one, one-to-many, many-to-one, and many-to-many) and converge verbal and visual media.

For business studies the applied strategies for branding, customer relationship and marketing have highest priority (Johnson, 1995, Aldrige et al., 1997, Faigin, 1997, Herbig & Hale, 1997, Hoffman et al., 1997, Lu & Yeung, 1998, Moon, 1998, Pardun & Lamb, 1999, Merwe & Bekker, 2003).

Education research developed and applied methodologies to evaluate the functionality and design of educational websites (Knupfer, 1997, Reeves & Dehoney, 1998, Gillani, 1998, Maddux, 1998, Maule, 1998, Hedberg, 2003). Gillani (1998), for example, argues that the time for just cool sites is over and we would need now more effective educational websites.

Information science merely focused on the evaluation of information quality online (McMurdo, 1998, Bath & Bouchier, 2003, Nicholas et al., 2003) and on the assessment of information visualization and navigation (Buagajska, 2003). McMurdo (1998) goes beyond information accessibility and quality by introducing various resources on website design and layout.

Studies conducted by library science merely concentrated on accessibility of information and general web design issues like navigation, currency, content/information, and authority (Everhart, 1997, 1998, Cohen & Still, 1999). Communication Studies are more interested in comparisons between traditional mass media like newspapers and their online counterparts (e.g. Li, 1998) or in the implementation of traditional research methodologies for online resources (McMillan, 2000, Wakeford, 2000, Roessler, 2002). In the field of political communication there have been done many surveys to evaluate the quality of political websites. Qualitative methods (Stone, 1996, D'Alessio, 1997, Margolis et al., 1997, 1999, Davis, 1999, Klinenberg & Perrin, 2000, Ferber et al., 2002, De Landtsheer et al., 1999, 2001, 2004) and quantitative approaches (Hill & Hughes, 1998, Gibson & Ward, 1998, 2000, West 2001, Schneider &

Foot, 2002, Rosenstiel et al, 2004) were applied to investigate how efficient and appropriate politicians, parties and candidates filled their sites with content.

A growing number of researchers are busy with the examination of the usability of websites (for example, Nielsen, 1993, 1999, 2000a, 2000b, Shneiderman, 1998, Spool et al., 1999, Krug 2002). These studies mostly focus on commercial websites. They provide very helpful knowledge but often focus too much on the functionality and usability while ignoring other important factors like emotions, aesthetics, fun and enjoyable user experiences.

All the mentioned studies provide very valuable insights and expertise but only show a fragmented picture of requirements for high quality (useful, useable and engaging) websites. Of course, one can argue that different types of websites (e.g. advocacy websites, political website, commercial websites, informational websites, news websites, personal websites) have different purposes and target different audiences and therefore require different evaluation criteria and standards. But our goal is the development of a more general framework and methodology adaptable for various types of websites. Similar to established standards for traditional media (e.g. gestalt principles for print resources), also different websites share common criteria necessary to be useful, usable, satisfying and engaging for the citizens.

We conclude from literature that the recent excitement about the power of websites to foster citizen's communication possibilities in previously impossible ways should not lead researchers to overlook the fact that the people are still interacting with a machine. A careful consideration of the interface issues is necessary (Dillon, 1990, Mack, 2000, Norman, 1988, 2003) to see how the users will interact best with the website interface. The graphical user interface (GUI) of websites reflects the increasing importance of nonverbal signs and digital images which refers to a changing semiotic system of human communication and interaction (Bolter, 1991). To increase the acceptance of websites by a wide public is important to understand that it is not enough to make a website functional but also usable,

compelling and engaging. There is a need for a model which weighs the visual/aesthetic aspects against the functional and technical aspects of web design (Thorlaciuss, 2002). Visual communication is an essential foundation for the design of interactive interfaces. The interface is visual and designed to communicate and it is interaction that distinguishes digital interfaces from the more traditional media.

### 3. *AESTHETICS AND EMOTION AS PART OF AN INTEGRATED FRAMEWORK*

The current literature is helpful in many regards, but focuses almost exclusively on the offered information, features of interactivity and usability without taking into account other important factors – like aesthetics and emotions - for evaluating the quality of public websites. We argue that an interdisciplinary approach with a theoretical and methodological basis is necessary to create as well as assess the quality of public websites. Websites are a new additional channel of communication with new features (graphical interface, motion, sound etc.) in a new environment (virtual, worldwide). The blurring relations between reading and writing, and between verbal and visual media as well as the transition from text-based uses of the Web to graphic and multimedia interfaces is asking for a more generic model of public Internet communication. Big parts of what we see, hear, read and think in our daily lives is stimulated and mediated by media, increasingly by electronic media. Similar to the effects of the book, telephone, TV and radio also the Internet will influence and change our social, cultural and political life. The Internet opens up a 'new world' with interchangeable roles of creator and viewer; it carries the potential for a media society shaped by citizens' participation and interaction. What we perceive and experience (see, hear, read) on the Internet/websites effects our perceptions of 'real world' (Schirmacher, 1999, Weinberger, 2002). Building on Schirmacher (1999, p. 2) "...aesthetics investigates perception as an inter-active process in which a person plays at the same time an active and a passive role. Aesthetics describes human perception as communication, a sharing of a common

world which constructs and deconstructs reality for us." we argue that it is necessary to integrate the aesthetics in a theoretical framework for the creation of engaging public (political, educational, cultural, artistic etc.) websites.

Much research over the past few years from the fields of usability, human-computer interaction and cognitive science has focused on the important field of developing more usable websites to improve the user-site interaction experience. However, in contrast to the ample amount of research focusing on the cognitive usability of web interfaces, only a few studies have focused on the aesthetic aspects of interfaces (Knupfer, 1997, Tractinsky, 1997, Thorlaciuss, 2002). Furthermore, the few studies dealing with aesthetic aspects of interfaces have limitations.

First, many authors seem to be aware of the importance and power of aesthetics and evoked emotions (Merwe & Bekker, 2003, Hill & Hughes, 1998, McMurdo, 1998, Gibson & Ward, 2000), but there is a lack of research and methodology to measure their quality. Mostly they do not go beyond counting the total number of graphic and multimedia files. We do not agree that the more pictures, animations or video files a site contains the more sophisticated, effective (Gibson & Ward, 2000) or "participation friendly" it is. A too busy site can also have the opposite effect and it depends how the pictures are arranged and which message they contain. Moreover, common statements like "one should apply eye pleasing aesthetics...", "...the site used nice colors" without further explanations or theoretical underpinning are too limited.

Second, several studies reduced the aesthetics to judge the beauty of a website or to assess applied graphic design principles. Our definition of aesthetics embraces the whole perception of the website by users/citizens. It addresses the arrangement and style of written words, elements of visual communication (e.g. pictures, empty space, body language), as well as the use of sound with which the website invites and challenges the user to follow its lead (Asmus, 1999, Schirmacher, 1999, Park, 2004).

The integration of aesthetic aspects of website interfaces – as additional channels

of communication - can improve their quality in many ways. As above mentioned, they are input for our senses (see, hear, feel etc.) and inform our thinking. Moreover, they influence our emotions. Being pretty skeptical towards the use of aesthetics in context of usable websites, finally also Nielsen (2002) discovered the importance of the 'look, feel and fun' factor for engaging and satisfying online experiences. "Designs that engage and empower users increase their enjoyment and encourage them to explore websites in-depth. Once we achieve ease of use, we'll need additional usability methods to further strengthen joy of use." (Nielsen, 2000a, p. 1). Norman (2003), for example, recently explained why attractive things might work better "Emotions, we now know, change the way the human mind solves problems – the emotional system changes how the cognitive system operates. So, if aesthetics would change our emotional state that would explain the mystery." (2003, p. 38).

Furthermore, aesthetics are not only important for the emotional component but can also improve the ease of use. Several studies have found a close correlation between perceived usability and user judgments of aesthetics (Knupfer, 1997, Kurosu & Kashimura, 1995; Tractinsky, 1997, Schenkman & Jonsson 2000, Kiana, 1999).

The fields of visual communication and interface design, film and television studies can help evaluating colors, images, typography, layout, sound as well as creating engagement through the effective combination of (learning) task and visual representation of the content (Laurel, 1993). These elements can draw the user's attention, assist completing his task, and improve the appeal of the site. Used in a wrong way they can distract, annoy or overwhelm the citizen by increasing the cognitive load.

Expertise from the field of interaction design is necessary to ensure motivated and engaged user. Preece (2002), for example, recommend the use of visual conventions borrowed from the real world, consistent visual metaphors, and the recognition of the learner/user as an actor (Laurel, 1993) to keep them engaged.

Interaction can also be stimulated and supported by appropriate applied elements

of visual communication (Wilson, 1993, Davis, 2002, Nielsen, 2002). Theories and perspectives from film, media analysis and from communication studies contribute to the development of a theoretical frame for successful interaction. Wilson (1993) presents some guidelines concerning the aesthetics and practice of designing interactive computer events. He claims, that before designers try to make the work interactive, they should understand the concept of interactivity and know why to make them interactive (creating versus consuming).

The list of above introduced research fields and their contribution to the creation of more useable, satisfying, pleasurable and engaging public websites is not exhaustive. It should be understood as an attempt to clarify the necessity for the development of a more interdisciplinary framework. However, there is definitely a need for further qualification. And instead of rejecting introduced frameworks and studies, the discussion below incorporates them and builds on them as an important platform for a more integrated theory and methodology for the creation and evaluation of public websites.

#### 4. *THE FRAMEWORK*

To develop a theoretical frame as well as a methodology for identifying what the website offers to the citizen/user, we begin to introduce the key properties of the new medium Internet. Building on the work of researchers studying the fundamental changes in our life world through the WWW (Rogers, 1986, Abramson et al., 1988, Weinberger, 2002, Burnett & Marshall, 2003) the following areas will be effected:

First, the style of communication: The increased scale of possible information exchange, the increased speed of information transfers, the reduced time for sending messages through data compression, the changed format of information through the combination of text, images, audio and video, the new directionality of communication enabled through the interactive potential of the Internet (synchronous and asynchronous two-way communication etc.), the individualized control is breaking the traditional publishing model (the individual

user gained power concerning what to view and what to publish).

Second, the Web is opening up a new world. The concepts of space (the content of the Web is 'near' and 'far' determined by what's linked with each other and the links are based on human interest), time (we as user decide when and for how long we interact with a website, based simply on what suits us), perfection (the design assumption of the Internet was that is an imperfect world – it celebrates our imperfection as a place where we can articulate our viewpoints, experiment, play, fail and try again), togetherness (the Web is a new social, public space – a shared place where we build, extend, and inhabit, but only to the degree we want to express our individual interests: many small faces, each distinct within the multitude) and knowledge (the web is a written world – the 3000 million people on the Web are its authors; huge amounts of knowledge can be build and shared together world widely) will be effected and might have significant implications - politically, economically, socially, and culturally - for our society.

Given these distinctive potential and the already existing frameworks, we try to detail the main four evaluation categories of useful, usable and engaging websites. These categories were already identified in earlier studies co-authored by the authors (De Landtsheer, Krasnoboka and Neuner, 1999; 2001, 2004). It follows that theories and methods for evaluating the content and design of existing websites can also usefully contribute to the production of new, qualitative and engaging websites.

#### 1) Content - information

The content category refers to the offered information in verbal (e.g. text, speech on video) and visual (e.g. graphs, illustrations, pictures) form. An excellent website provides focused content, which serves the needs of visitors. The appropriateness of information depends, of course, on the objective of the provider, on the type of the website and on the targeted audience (e.g. commercial or advocacy website). The following issues, for example, are of general interest and can be adapted in correspondence with the nature and purpose of the site:

Quality of information (e.g. spelling and grammatical mistakes, accurate and reliable,

authority, copyright, currency, quality of writing for the web, etc.)

Appropriateness of information (the relevance for the site's purpose, no 'meaningless' content, types of information, in relevant community language ect.)

Scope of information (the breadth or narrowness of the resource, its depth and level of detail, leaving out nothing significant) Etc.

#### 2) Interactivity – communication settings

Following McMillan (2000, 2002) three types of interactivity can be distinguished: human-to-human interaction, human-to-documents interaction and human-to-system interaction.

Interactivity is mainly about the directionality of communication and level of control over communication. The direction of communication differs between one-way from the source to the receiver, two-way communication between provider and user, or multidirectional communication between any number of sources and viewers. The control of communication embraces one-way sender controlled communication e.g. dissemination of marketing or political marketing messages, or interchangeable roles between author and reader, break down of former hierarchies between sender and receiver in form of responsive dialogues. The dimensions of communication direction and participant control can be applied to all three forms of interactivity mentioned below.

Concerning user-to-user interactivity it is important that we use communication settings which enable the users to have reciprocal exchanges of information e.g. e mail contact, chat rooms, instant messaging tools etc.

Human-to-documents interactivity can be seen how active audiences or users interpret, manipulate and use the media messages. For example the presence of possibilities for the creation of interactive fiction, downloadable documents, interaction possibilities with content creators and actual creation of content; playing games or quizzes, online memberships, Mud's and MOO's, etc.

Human-to-system interaction refers to the interaction between people and the computer/website interface e.g. computer based instructions like online help, online formulas for various transactions, feedback from the computer in learning programs,

possibilities to manipulate the computer and obtain information e.g. the use of databases, spreadsheets.

Given the interactive potential of websites and the three dimensions of interactivity, we can examine how interactive the applied communication strategies of the site are.

### 3) Usability – easiness of use

Building on Preece and colleagues (2002, p. 14) we define usability of websites as products which are 'easy to learn, effective to use, and enjoyable from the user's perspective. It involves optimizing the interactions people have with interactive products to enable them to carry out their activities at work, school, and in their everyday life.' In other words, a website should be – also depending on its main purpose - satisfying, enjoyable, fun, entertaining, helpful, motivating, aesthetically pleasing, supportive of creativity rewarding and emotionally fulfilling.

It is about the ease of use when people are navigating through the site. The more easy to use the website is, the more they will feel encouraged to explore the site in-depth, to interact with it and to visit it again (Nielsen, 2000a, Krug, 2000, Preece, 2002). How useable a website is can be measured, for example, by having a closer look at the quality of the following features:

Navigation (user orientation, information hierarchy and architecture, etc.), links (changing color of links, name of the links, ect.), graphic and multimedia files (containing message, download and loading time), search machines, online documentation, online help, recognizable/clear purpose of the site, browsability, accessibility, used technology etc.

### 4) Aesthetics – experience and perception

When considering the design of websites, the focus tends to gravitate to common issues of information, interactivity and usability. Even in the discussions regarding the website's usability and human factors, the issue of user experience, or overall their aesthetic experience, is rarely addressed. Our definition of aesthetics embraces the whole perception of the website by users/citizens. It addresses the arrangement and style of written words, elements of visual communication (e.g. pictures, empty space, body language), as well as the use of

sound with which the website invites and challenges the user to follow its lead. It refers to the mediated tone and mood of the website's content.

The applied aesthetics influence many important issues for informative, user friendly and engaging websites: the usability of a site, the information presentation, the credibility of the site, the attractiveness, the 'look and feel', the visual appeal, and so on. More and more scholars start to discover positive correlations between aesthetics and other success factors of a website. Tractinsky (1997, p. 2), for example, claims "... recent research on the visual aesthetics of computer interfaces suggests that aesthetics is a strong determinant for user's satisfaction and pleasure... empirical studies in the field of HCI have also found that the aesthetic aspects of various computing products serve an important role in shaping user's attitudes in general...". Kim, Lee and Choi (2003) performed an empirical study of the quantitative relations between design factors and emotional dimensions. Their study confirmed a correlation between examined design factors and positive emotions.

Several studies have found a close connection between perceived usability and user judgments of aesthetics (Kurosu & Kashimura, 1995; Tractinsky, 1997, Schenkman & Jonsson 2000, Powazek, 2002). Edward Tufte wrote, "Skillful visual design of computer screens - with care given to color, typography, layout, icons, graphics, and coherency - substantially contributes to quality and usability" (1994, p. 32). Schenkman and Jonsson (2000) concluded that the best predictor for the overall judgment of a website was its beauty perceived by the user. Powazek (2002, p. 59) concludes "...it's hard to quantify exactly how much the visual design of a community space contributes to quality of the contributions, it's impossible to deny that one directly influences the other."

In our context, the term aesthetics embraces issues like the use of sound, graphic design and gestalt principles, visual communication elements, animation techniques, the emotional and associative dramaturgy of the website content, the used language style. Important criteria in this context are, for example:

Use of color, typography, graphics; the site composition and balance; the whole layout (clear, consistent, easy to read, not too busy); the mediated tone and mood of the site (through sound, pictures, used language style etc.); graphic enhance without cluttering and confusing; used metaphors, semiotics etc.

More generally speaking (Powazek, 2002) it is about the design for the target audience, the design for flexibility, the design for experience, the design for simplicity, the design for readability, the design for beauty and the design for community. Moreover, the aesthetics always depend on the cultural context within which they are applied (Tractinsky, 1997).

##### 5. CONCLUSION

The intention of this paper is to show the need for bringing single areas together in one framework to provide a broad picture of the quality of a website. The suggested categories can still be better theoretically underpinned, conceptualized, and categorized. Moreover, their proper application always depends on the purpose and nature of the website and the cultural context. Especially, the aesthetics should no longer be ignored when talking about useable and engaging websites since they can play a crucial role in motivating the citizens to get engaged with the content of the site.

The movement from book to screen, from print to digital with changed concepts of space, time, togetherness and communication provides so many surprises, opportunities, hopes and fears that none of can say how it will play out. Our experiences in the 'virtual world' will effect our perceptions and activities in 'real world'. With changed media and communication also the concept of the public sphere and democracy changes. But how we judge these changes is less important than joining together our expertise for the active creation of this new public space/new part of our public sphere. A shared common world - with public and private discourse – requires the people's participation. In order to design meaningful and attractive websites, designers must understand how citizen use and perceive the site they visit. Therefore,

the user should be in the center of the design. Moreover, user and perceptions may vary among various types of websites and tasks, so that we should start with specific contexts before we draw general conclusions.

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# Access Control for e-Business on MOPASS

Kilho Shin and Masahiro Taguchi

**Abstract—** *MO(bile)PASS(port) is a consortium lead by Japanese major electric appliance manufacturers for the next-generation smart card. Its scope includes the software middleware that bridges between the smart card and real e-Businesses. In fact, the specification of Ticket Authentication Protocol, which provides access control functionality applicable to a wide range of e-Businesses (e.g. digital ticketing, digital content distribution), is under consideration by MOPASS. The specification is open and direct since it is based on a new methodology characterized by user's access-rights being straightforwardly authenticated by PKI. In addition, it covers the functionality of revoking, duplicating and transferring of access-rights in a peer-to-peer manner.*

**Index Terms—** *Access control, authentication, e-Business, smart card, MOPASS, peer-to-peer, PKI*

## 1. INTRODUCTION

**M**OPASS (<http://www.mopass.info>) is a consortium for the promotion of the next-generation smart card named MOPASS Card. The Japanese major electric appliance manufacturers, Hitachi Ltd., Matsushita Electric Industrial Co., Ltd. and Toshiba Corp. are leading it and more than 60 companies from diverse fields participate in it. In this paper, by smart card we mean an IC card with a micro computer embedded therein.

Not merely MOPASS focuses on the hardware architecture of MOPASS Card but also it aims to pursue the possibility of MOPASS Card being widely used in e-Business.

As is widely accepted, the smart card will definitely play more and more important roles in the future e-Business scenes due to its security capability to protect confidential information and vulnerable programs from adversarial accesses (e.g. theft, tampering and interruption). This requirement comes from the observation that e-Business practices cannot help involving crucial information being processed at the user's point. For example, when consumers order goods over the Internet, they are possibly required to prove their identity for payment based on their secrets (e.g. credit card number, PIN). If a program running on a client PC executes the calculations involving the secrets, they would be exposed to the threat of being stolen. In fact, the current architecture of PC only provides very weak means to prevent such adversarial behaviors of malicious programs.

The smart card has a potential to solve this problem and this is the reason why applying the smart card to e-Business is attracting a lot of attention of the industries. The framework of the smart card securing e-Business is very simple: a program confined within the smart card executes all the sensitive calculations and does not reveal anything but the safe results; a host program running on a PC receives the results and executes the consecutive calculations.

Based on this fundamental framework, MOPASS aims to define MOPASS Card as a security anchor for diverse e-Business services. Eventually, MOPASS not only will implement in MOPASS Card those security functions that are commonly useful for e-Business, but also it intends to open their API (Application Program Interfaces) to the public.

Currently, MOPASS has approved that the access control functionality that is commonly applicable to various eBusiness

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services is an important instance of the functionality to be implemented in MOPASS Card. This is because, as far as services are of the nature that only authorized users (e.g. the users who have paid for the services) are to be permitted to enjoy them, access control is commonly mandatory.

Nevertheless, current e-Business services tend to take the redundancy of deploying respective methods of access control. This redundancy causes the following disadvantages.

- The user and the provider of e-Business services have to take the overhead of supporting multiple methods (e.g. retaining plural smart cards).

- System developers are obliged to pay the redundant cost of developing different methods for different e-Business services.

- The exchangeability between e-Business services is harmed. For example, the content data currently tailored to respective content distribution systems are not mutually exchangeable.

Based on this understanding, the authors have proposed to MOPASS a protocol specification of access control, which supports the currently recognized requirements. The protocol is named Ticket Authentication Protocol (TAP) and its specification is given in [10].

By TAP, the user could use his or her single MOPASS Card as a *universal token* to access arbitrary services (Figure 1).

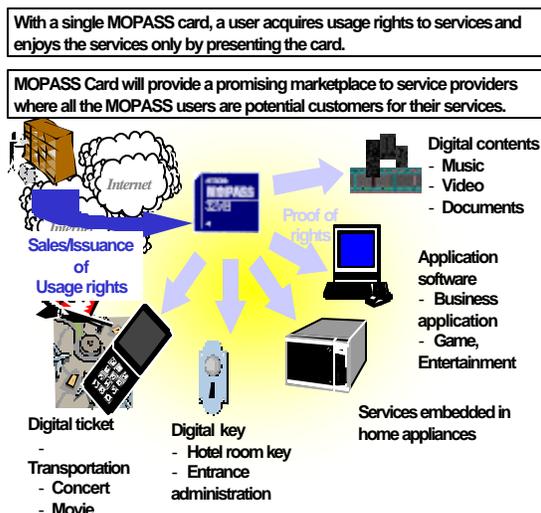


Figure 1. Aim of MOPASS Card

From a viewpoint of the service provider, they would be released from the burden of developing and distributing programs to be installed in smart cards, since all the necessary functions with respect to the access control functionality are provided through the open interface of MOPASS Card. Another important feature of TAP is to provide methods to revoke, consume, duplicate, modify and transfer an issued access-right in a peer-to-peer manner. For example, transferring an access-right is executed through communications between the two MOPASS Cards of the sender and recipient users. At the same time, the methods are secure in the sense that their execution never infringes the rules that the issuer of the access-right specified when it issued the access-right.

Currently, MOPASS has accepted TAP as a working draft, and a business trial is under preparation, which is going to involve real content and real consumers.

## II. DESIGN PRINCIPLES

### A. ARCHITECTURAL PRINCIPLES

The access control functionality of TAP is designed to support the following architectural principles.

#### 1) Independence and Applicability

The access control functionality shall be totally separable from any other functionality (e.g. payment) and commonly applicable to a wide variety of services as far as they need it.

#### 2) Support of PAC Model

PAC Model (3.A) introduces three independent players, namely Provider, Application and Card, and formalizes the processes of access control as communications between them.

- *Provider* denotes a provider of e-Business services.

- *Application* is a program, device, apparatus or their arbitrary combination to render e-Business services for the sake of their users.

- *Card* denotes MOPASS Card retained by a user of e-Business services. PAC Model tries to model the real world faithfully and consequently will make it possible to support a wide range of the real business models.

### 3) *No Card Application Programs*

In the conventional usage of smart card, it is common that service providers are required to develop card application programs for their own services and to persuade users to install the programs in their smart cards. This convention is, of course, a significant burden for both the service providers and the users.

### 4) *Open Platform Design*

Arbitrary systems shall be able to utilize the access control functionality of MOPASS Card through open interfaces. In particular, users' access-rights shall be authenticated only based on public information such as public keys of the public-key-cryptography.

Also, this principle means the stronger requirement that Provider, Application and Card shall cooperate with each other without knowing each other's secrets at all.

### 5) *Non Server-Centric Design*

Each phase of the access control functionality of TAP shall be completed through communications between two of Provider, Application and Card. For example, Provider and Card cooperate with each other in the phase of granting rights and no other party is involved. Transferring an access-right from a user to another is carried out by cooperation between two Cards of the sender and the recipient.

## B. *FUNCTIONAL PRINCIPLES*

TAP also supports a plurality of functional requirements, some of which are shown below.

### 1) *Enforcement of access rules*

In practice, an access-right accompanies access rules (e.g. an expiry, permitted usage times). Application and Card, cooperating with each other, shall enforce the access rules when the right is executed.

### 2) *Manipulation of access-rights after issuance*

Manipulating the access-rights that were granted in the past may be important in practical business cases. In particular, revoking, consuming, duplicating, modifying and transferring access-rights are important, because their combination covers the most part of the required manipulations: *revoking* an access-right is to make it useless; *consuming* an access-right is to restrict its execution up to a specified number of times; *duplicating* an access-right is to make its

duplicates; *modifying* an access-right is to change the access rules accompanying it; *transferring* an access-right is to transfer it from a user to another.

To prevent abuse of those manipulations, they shall not be executed beyond the permission specified when the access-right was initially issued.

### 3) *Authentication of Application by Card*

Since PAC Model defines that Provider and Application are mutually independent, Provider needs means to authenticate Application during Provider's proprietary service is being rendered. To avoid the overhead of communications between Provider and Application, Card shall authenticate Application on behalf of Provider.

## III. *UNDERLYING CONCEPTS*

Two important concepts underlie TAP. One is PAC Model and the other is Digital Qualification.

### A. *PAC (Provider-Application-Card) MODEL*

PAC Model is important because it defines chief players of the access control functionality of MOPASS Card and because it clarifies the scope of the functionality.

#### 1) *The roles of Provider, Application and Card*

PAC Model gives the following roles to Provider, Application and Card, and further introduces *Ticket*, which are digital credentials representing permission for a particular user to render a particular service.

Provider grants a user an access-right to a particular service by issuing *Ticket*. *Ticket* is deliberately designed secure so that it can be delivered even by insecure means (e.g. http, SMTP).

Application inspects *Ticket* to verify that it properly represents the access-right of the relevant user. For this, Application receives a proof from Card that the user retains. Since the proof is generated from the secret proper to the Card, any different Card can never generate the same proof.

Card not only sends a proof to Application but also authenticates Application on behalf of Provider. An important feature of PAC Model resides in that Provider, Application and Card are defined to be totally independent of one another.

Provider being independent of the other two is necessary to model the real world faithfully and therefore to support a wide range of the real business models. For example, some electric appliance manufacturers are currently selling portable memory devices ([3]), which play the equivalent role of Card in their audio content download services: an audio player renders the audio contents only when they are stored in the memory device. While the manufacturers play the roles of the vender of Application and the issuer of Card, a record label, which is totally independent of the manufacturers, does the role of Provider.

In contrast, the independence between Application and Card is not necessarily to model the real world. In fact, the vender of Application and the issuer of Card in the previous example are the same manufacturers. However, this dependence is recognized as one of the most significant negative factors that are currently blocking spread of the smart card, since only governments, banks and credit card companies are currently recognized as the organizations that are capable of distributing smart cards over consumers at an inexpensive price.

Also, the multi-application operating systems of Java Card API and MULTOS ([2]) seem to support this requirement. With Java Card API and MULTOS, card application programs can be downloaded onto smart cards after the issuers issued them.

## 2) *The scope of TAP*

PAC Model assumes that Provider, the vender of Application and the issuer of Card are independent of one another. This assumption leads us to the conclusion that TAP shall rigidly specify the syntax, semantics and encoding rules of those messages to be exchanged among the players since they could not cooperate with each other otherwise.

Actually, the scope of TAP includes the following messages.

- A message to request Provider to issue Ticket.
- Ticket that Provider issues in response to the Ticket request.
- A sequence of messages exchanged

between Application and Card for the mutual authentication.

- A message (`AppDef`) that Provider generates to describe Application(s).

By contrast, although Application and Card cooperate with each other to render the services that are proprietary properties of Provider, PAC Model defines that TAP shall NOT specify any concrete means for Provider to establish trust with Application or Card. This is because means of establishing the trust is in practice affected by the actual business circumstances to which TAP is applied. For example, even if TAP specified that a single authority shall issue all the certificates to establish the trust, all the player could not accept the policies of the authority.

What TAP specifies regarding the trust is only that the consequence of establishing the trust must be Provider accepting the public keys of Application and Card. Provider should cope with those accepted public keys as follows.

- Provider specifies Applications' public keys in the data of `AppDef` (5.A.1) and publicizes them.

- Provider executes key agreement protocols with Card using the public keys of Card (5.B).

## B. DIGITAL QUALIFICATION

To support the principles of *Independence and Applicability* and *Open Platform Design*, TAP is based on a new methodology for access control, namely Digital Qualification ([11]). Digital Qualification applies the public-key-cryptographic techniques to access control in a straightforward manner.

### 1) *Identifying a service*

Provider generates a public key pair and assigns it to a service that Provider intends to provide to users. While the public key of the pair is publicized as a public identifier of the service, Provider shall store the private key secretly.

### 2) *Granting an access-right*

When a user requests an access-right to the service, Provider generates Ticket by transforming the private key of the service according using a certain cryptographic method. Ticket is issued to the requesting user.

### 3) *Authenticating an access-right*

Authenticating the user's access-right is carried out by inspecting Ticket. Application uses the public key assigned to the relevant service to inspect Ticket and executes calculations compliant to the corresponding public-key-algorithm.

Thus, Digital Qualification shows a clear contrast with the legacy of the initial idea of PKI (Digital Identification): the result of the execution of the public-key-algorithm in Digital Qualification is authentication of an access-right of the user, while it is authentication of the identity of the user in Digital Identification.

## IV. RELATED WORKS

Applying PKI to access control itself is not new. The traditional method using ACL (Access Control List) is comprised of two steps: the first step to authenticate the user who is requesting access; the second step to look up ACL to inspect whether the user actually has the access-right. It is common that the first step is based on PKI. This ACL-based method is redundant in comparison with Digital Qualification, which achieves the same goal by a single step and doesn't require a user to reveal his or her identity.

In addition, looking up ACL requires extra processing time and network connection. In addition, maintaining a huge ACL is a troublesome task especially in terms of security, since modification of ACL would result in unauthorized access. Also, providers of nonfree services may not be interested in who the user is, but in whether the user has paid and not. Moreover, revealing the identity during authentication may be regarded as infringement of the privacy.

Plural companies currently deploy respective access control methods in their digital content distribution services ([4, 6]), which are commonly based on the symmetric-key cryptographic techniques. This approach improves the performance of execution but sacrifices the supporting of *Open Platform Design*. Furthermore, since the methods tend to be associated with particular contents formats, the design

principle of *Independence and Applicability* is not supported.

## V. OUTLINES OF SPECIFICATION OF TAP

This section gives a brief illustration of the technical content of TAP.

### A. *Important Data Types*

First of all, two important data type, `AppDef` and `AppRule`, are illustrated.

#### 1) *AppDef*

To prevent an abuse of services, Provider must draw a line between the trusted Applications that Provider permits to render its proprietary services and all the others.

The data type `AppDef` is defined to support this requirement. Provider generates an instance of `AppDef` and specifies the public keys of the trusted Applications in it. Further, Provider publicizes it and Card refers to it to authenticate Applications.

#### 2) *AppRule*

The data type `AppRule` is to describe the access rules that Application and Card shall refer to in rendering the associated service. TAP specifies that every Ticket shall contain `AppRule`.

`AppRule` is comprised of the elements of `ClearPart` and `OpaquePart`. Card interprets and executes the access rules specified in `ClearPart`, while Provider specifies application-specific access rules in `OpaquePart`, which only particular Application can interpret.

### B. *Granting access-rights*

On receipt of a request from Card, Provider generates Ticket.

For generating Ticket, Provider and Card agree on a one-time secret  $k$  in accordance with the unilateral version of Menezes-Qu-Vanstone Key Agreement (MQV-KA, [5, 7]). MQV-KA is a variant of Diffie-Hellman Key Agreement (DH-KA, [5, 8]) and satisfies the following properties.

- $k$  is affected by the public key of Card.
- $k$  is always random, and therefore a different secret is generated for a different Ticket.

To generate Ticket, Provider uses the secret in combination with `AppDef`,

`AppRule` and the public key `S` assigned to the requested service.

- The involvement of the random secret is to realize the revocation of `Ticket`.

- The involvement of `AppDef` and `AppRule` is to prevent them from being tampered with (7.B).

- The involvement of `S` is to prevent forging `Ticket` (7.A).

On the other hand, `Card` stores the secret in its secure storage and uses it to prove the user's access-right (5.C) against `Application`.

### C. Authentication Protocol

`Application` and `Card` communicate with each other for respective purposes: `Application` aims to inspect `Ticket` to authenticate the user's access-right, while `Card` aims to authenticate `Application`.

As the base algorithms for `Application` to verify `Ticket`, TAP deploys two instances of the public-key algorithms: Schnorr Identification (SI, [9]) and DH-KA. The former is based on the zero-knowledge interactive proof techniques and is known very efficient, and therefore is suitable for the business cases where the efficiency is strongly required (e.g. digital ticketing). By contrast, the execution of the latter requires heavier calculations but it provides the functionality of decrypting secret data (e.g. a content key used in digital content distribution).

Since `Ticket` is generated from the secret `k`, `AppDef`, `AppRule` and the public key `S`, `Card` has to use those values to respond to `Application`.

On the other hand, authenticating `Application` is realized based on the MAC (message authentication codes) techniques. `Application` and `Card` share a MAC-generation key for a start and `Card` verifies MAC sent by `Application`. Since the key is derived from the public key of `Application`, which is specified in `AppDef`, verifying MAC is identical with authenticating `Application`.

### D. Revoking, consuming, duplicating and modifying Ticket

Given `Ticket` that `Provider` correctly generated, `Card` is able to revoke, consume, duplicate and modify the `Ticket`. `Card` executes the manipulations only when

*privileged* `Application` instructs `Card` to do so. Whether or not `Application` is privileged is specified in `AppDef`.

To revoke `Ticket`, `Card` deletes the one-time secret `k` from its secure storage: since `Card` can no longer respond to `Application` without `k` (5.C), `Ticket` becomes totally useless.

Consuming `Ticket` is used to limit the number of times of rendering services. The limit is specified as the value of the `AvConsumeTimes` element of `AppRule` (5.A.2). The following are the steps that `Card` follows to consume `Ticket`.

1. Verify that `Application` is privileged to instruct `Card` to consume `Ticket`.

2. Verify that the value of `AvConsumeTimes` of `AppRule` is positive.

3. Modify `AppRule` so that `AvConsumeTimes` decreases by 1.

4. Generate a new one-time secret randomly.

5. Generate a new `Ticket` based on the new secret and the modified `AppRule`.

6. Discard the initial secret `k` to revoke `Ticket`.

Thus, the initial `Ticket` is revoked and a new instance of `Ticket` is generated as a result of consuming `Ticket`.

Duplicating `Ticket` is executed following the steps similar to the steps for consuming `Ticket`, except that two new instances of `Ticket` are generated as a result.

Modifying `Ticket` is used to modify `AppRule` arbitrarily. Privileged `Application` is responsible for specifying the modified `AppRule`.

### E. Transferring Ticket

Different from the other manipulations on `Ticket`, transferring `Ticket` is executed between two `Cards`. One is owned by the user to whom `Ticket` was initially issued and the other is owned by the user who will receive the transferred `Ticket`.

Briefly speaking, the recipient `Card` sends public keys to the sender `Card` and the sender `Card` returns the transferred `Ticket`. Since neither the public keys nor `Ticket` is secret data, the communication can be executed by any means including insecure protocols (e.g. http, SMTP) and exchange of physical storages (e.g. floppy disk).

The number of occurrence of transferring Ticket is limited by the value of the `AvTransferTimes` element of `ApplRule`, which Provider specified when it generated Ticket. The sender Card follows the steps stated below.

1. Execute MQV-KA with the recipient Card to share a new one-time secret. The public key of the recipient Card is used in the calculation.

2. Verify that the value of `AvTransferTimes` is positive.

3. Modify `ApplRule` so that `AvTransferTimes` decreases by 1.

4. Generate a new Ticket which involves the newly shared secret and modified `ApplRule`.

5. Discard  $k$  to revoke Ticket.

## VI. SUPPORT OF DESIGN PRINCIPLES BY TAP

Since Section 5 shows all the functional principles stated in 2.B are supported, this section focuses on support of architectural principles.

Since TAP provides a specification for access control protocols at an abstract level, *Independence and Applicability* is apparently supported. TAP also specifies the syntax, semantics and encoding rules of the messages to be exchanged among Provider, Application and Card, and therefore supports *PAC Model*.

The protocols specified in TAP are to be executed between two of Provider, Application and Card. Especially, since neither server nor card application program is involved, *No Card Application Programs* and *Non Server-Centric Design* are supported. Moreover, TAP is public information and the secrets to be shared between players are all random and one-time. This means that *Open Platform Design* is also supported.

## VII. CONSIDERATION OF SECURITY

### A. Security against forging Ticket

The definition of Ticket is carefully designed so as to satisfy the strongest sense of the security: even if an adversary collected all the valid Tickets ever issued, the adversary could not extract any

information useful to forge a new instance of Ticket. This property is provable assuming a secure pseudo-random-generation function  $h(x,y)$ , which is to be used in the definition of Ticket.

### B. Security of the authentication protocol

The authentication protocol (5.C) is secure in the sense of the Bellare-Rogaway's definition ([1]). In more details, it satisfies the stronger sense of security (see also 7.C): if Application succeeds in verifying Ticket, it doesn't share the MAC-generation key with anyone but Card. It is also provable that Card reveals nothing to whoever impersonates Application.

### C. Integrity of `ApplDef` and `ApplRule`

Tampering with `ApplDef` and `ApplRule` could be a serious threat to the authentication protocol, since it would allow impersonation of Application and abuse of services. However, the authentication protocol satisfies the property that, if tampered `ApplDef` or `ApplRule` is input to Application and/or Card, Application always fails in verifying Ticket. The following is a brief explanation of this property.

If either `ApplDef` or `ApplRule` input to Card is tampered with, Card no longer correctly responds to Application since the response from Card is calculated using both `ApplDef` and `ApplRule`.

If either `ApplDef` or `ApplRule` input to Application is different from that input to Card, Card fails to verify MAC since Application generates MAC using both of `ApplDef` and `ApplRule`.

### D. Security of Revoking, Consuming, Modifying, Duplicating, and Transferring Ticket

Since tampering with `ApplDef` to impersonate privileged Application or tampering with `ApplRule` to abuse the manipulations makes Card return only an incorrect response, the adversary gains nothing (7.C). However, the adversary may attempt to make valid Tickets useless by impersonating privileged Application. Although Card never returns the valid response, it would be misled to discard the one-time secret  $k$ . This attack is, of course, avoided by letting Card to verify Ticket in the same way as Application does.

### VIII. CONCLUSION

The access control functionality that supports the design principles of *Independence and Applicability*, *PAC Model*, *No Card Application Programs*, *Open Platform Design* and *Non Server-Centric Design* will definitely provide smart card with the potential to be used as a *universal token*: a user could access arbitrary services only by presenting his or her single smart card to prove his or her access rights.

The authors have developed a specification of access control protocols that supports all the principles. Moreover, the specification satisfies security requirements at a very high level: most of security achievements are proved based on a mathematical model. The specification is proposed to MOPASS, which is a consortium for the next generation smart card.

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# Critical Skills and Knowledge in Development of e-commerce Infrastructure

Seppo J. Sirkemaa

**Abstract—** *In general, information systems development is based on existing systems. This is also the case with information technology infrastructure (IT infrastructure) because all earlier development work and decisions impact the reliability and flexibility of the infrastructure. This makes management of IT infrastructure development an important challenge.*

*Information systems rely on infrastructure in sharing data and information. Here we focus on IT infrastructure and discuss what skills and knowledge is needed in development of e-commerce infrastructure for the company. We argue that the skills and knowledge of persons involved in the development process is a critical resource.*

**Index Terms—** *development, e-commerce, information technology, infrastructure, knowledge, skills*

## 1. INTRODUCTION

**I**N this paper we focus on information technology infrastructure (IT infrastructure) and discuss its role in the company. The question here is that what skills and knowledge is needed in developing a robust and flexible IT infrastructure for e-commerce purposes.

Investments in information technology are often considerable and they impact the organization in many ways [1]. In information systems development it is important to identify the key technologies and solutions, otherwise investments may soon become obsolete. Furthermore, expertise and knowledge in information technology is needed in developing services for business purposes.

Open discussion and interaction is important, they are needed in the development group so that the goals become clear to all who are involved. Consequently, understanding what technology can do and what benefits it brings in the company is a key issue [2].

## 2. IMPORTANCE OF IT INFRASTRUCTURE

Information technology infrastructure is the basis of other systems that are used in the organization. It is the enabling platform that connects users and their workstation to common resources [3], [4], [1]. IT infrastructure also connects different locations and is the route to other networks (e.g. Internet) and to business partners and their IT infrastructure.

Information technology infrastructure can be divided into two components, the technical IT infrastructure and a human IT infrastructure [5]. Here the technical IT infrastructure is company's technology and information that is intended to be shared [6]. Technical IT infrastructure is more than different computers, hardware devices and components. It also includes common applications, data and practices in processing information [7].

Because information technology infrastructure consists of both hardware and software components it – IT infrastructure - can be defined also differently. Another definition of IT infrastructure divides it into three elements [3], [8], [9]: Firstly, there is a technical element. It refers to hardware like workstations, servers and devices that are needed to connect computers together. Secondly, shared services are an element that includes software components. For example, common mail system or databases that are used by different business

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applications and users across the organization are shared services and part of the IT infrastructure.

Information technology infrastructure includes also a human dimension. IT skills, expertise, management practices, competencies and commitment - the human IT infrastructure – is even more important than technical issues [5]. The human element binds technical components into IT infrastructure services that are shared in business processes. This viewpoint highlights the importance of human element in information technology management [Error! Bookmark not defined.], [9], [8], [1].

### 3. FLEXIBILITY OF THE IT INFRASTRUCTURE

Existing infrastructure and information system sets the guidelines for the IT infrastructure development process. Therefore, openness of the infrastructure is a key feature. Openness refers here to the ability to fit components from different manufacturers together, but it also means that different systems and processes can be integrated [4], [1]. Also standards and standards compliance is needed in IT infrastructure development. Without them it would be difficult and expensive to make different infrastructures and systems that interconnect. These issues are important also in development of e-commerce infrastructure.

The flexibility of the infrastructure is an important issue [10]. McGarty [11] points out that it must be possible to expand and modify the IT infrastructure when requirements change. Especially in e-commerce applications the system is expected to be almost infinitely scalable: for example, the amount of potential customers in the e-commerce site can increase rapidly, and therefore it should be easy to add processing power and capacity. The bandwidth and security are also important issues, especially if the site is inside company's local area network. The e-commerce infrastructure must also support interfaces to different partner's infrastructures. For example banks and companies in logistics may need to be interconnected.

### 4. TAXONOMY OF SKILLS AND KNOWLEDGE IN IT MANAGEMENT

In general, skill relates to a capability to do something concrete, whereas knowledge refers to abstract reasoning [12]. What are skills and knowledge in information technology management? In maintenance activities are both concrete skills and abstract thinking needed. For example, troubleshooting involves finding the problem (abstract thinking) and then fixing it (concrete skills involved). Furthermore, reliability of the infrastructure is based on careful maintenance and disaster planning – there is a need to protect the system against viruses, intruders etc. The level of skills and knowledge in maintenance materializes in the robustness and reliability of the information system. This is also called as the “trustworthiness” of the information system in the organization [13].

IT related skills, knowledge and experience are also critical when new information systems and services are being developed for business purposes. This is an area where the most significant business capabilities and value can be created [3]. Support from top management is needed – and this does not refer to money alone. It is vital that the business strategies and IT development activities are interconnected. As noted by McKay and Brockway [3], information technology brings added value to business only if it supports business needs and is managed by skilled IT people.

Development of information systems is a challenging task because many systems impact the organization deeply. They are shared among users that work in different departments and geographical locations.

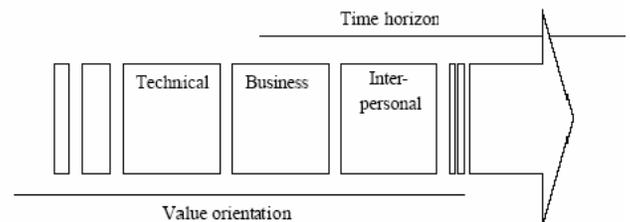


Figure 1: Domains of skills and knowledge

Furthermore, information systems can be available across several companies and industries. Therefore the role of IT

management is critical in development of systems and services that meet the needs of users and create value to operations [3], [4]. Here technical skills and knowledge alone are not enough.

In general, people who are involved in IT development should possess skills and knowledge in a wide area [14]. These can be divided into three main domains: technical, business and interpersonal skills and knowledge [15], [16]. Feeny and Willcocks [17] have found two more perspectives, value orientation and time horizon (Figure 1).

The human element, knowledge and skills of people involved in IT development is considered as a critical success factor in information technology development and use [2], [15], [5]. We argue that this is also the case in development of e-commerce infrastructure.

#### 4.1. Technical skills

It is evident that technical understanding is required in IT development. There is a need for both detailed technical knowledge in the technology in question and also a broader understanding that covers the areas that the technology will affect is needed. Technical knowledge is important, and if company's own expertise is weak it is a good idea to look for outside advice. For example, using a consultant in security planning may be a valuable investment.

Technical skills should not only be seen as limited technical knowledge like knowledge of technical devices, solutions and alternatives. There is also an interpersonal dimension involved as development alternatives and possibilities are often mapped during discussions with outside experts and vendors. Technical knowledge, interpersonal skills and experience are needed to judge a technology, product and a solution. Understanding the technological capability can also be important in monitoring partner and vendor relationships. Here previous experiences of a technology or a partner are in an important role.

It is important to notice that technical knowledge and expertise is needed at all managerial levels that are involved [5].

Making decisions that have critical operative importance today and affect future development calls for understanding of the technology and the system that is being developed – all who are involved in the development process should mutually understand the key questions and concerns. This is possible if the persons have reached a “know why” stage and are therefore able to use the same language, interact and understand the development area and challenges that are involved.

#### 4.2. Business skills

Information technology is used in business processes, and it makes it possible to achieve strategic goals of the organizations. Therefore business understanding is critical in IT development. This is also the case in development of e-commerce platform.

Business understanding is often linked to leadership, business systems thinking, relationship building, informed buying and vendor development [17]. These skills and capabilities are important in information technology management as well [18], [15], [5]. As Feeny and Willcocks [17] write:

*“IS professionals deliver core IS capabilities by exploiting assets that previously enabled their successful IS careers: rapidly absorbing new information, building mental models of how things work, and using these models for exploration.”*

The importance of business understanding in IT development is clear. It could even be argued that IT development requires so many business skills, that business people and managers should develop information systems instead of IT people. Nevertheless, IT people with technical expertise are also needed – but also people with business understanding must be involved in IT development.

#### 4.3. Interpersonal skills

In general, interpersonal skills are important in IT development. Information technology development is based on cooperation and mutual understanding between the people who are involved in development work. Interpersonal skills are at stake in both internal and external relationships and interaction.

People in the IT department should have good interpersonal skills so that others in the organization could understand them – technical jargon should be avoided. Narrow technical orientation may lead to misunderstandings and problems in the development work. IT people should also understand business requirements, processes and the needs of the users. Furthermore, IT people need to convince the business people that information technology helps in achieving business goals.

Interpersonal skills are needed also in external relationships. For example, working with outside service providers calls for interpersonal skills. Interpersonal skills are especially critical when showing business partners that their values, goals and problems are respected and understood.

#### *4.4. Value and time Horizon*

Information technology involves large investments in technology that may be used only to a given purpose [14]. However, developers should build systems that are robust and operate reliably for a long time [4], [19]. The systems should also be flexible so that future expansions and change in needs can be incorporated [10]. This highlights the importance of development of a system that serves as a basis for operations, but still is open for modifications. The need for an IS-strategy is obvious – it helps in operative decisions and brings a longer time perspective to IT development.

How should skills and knowledge in IT infrastructure development reflect these requirements? Obviously, some skills are more oriented to short-term interests than others. In technical maintenance the perspective is short as the goal is to solve a problem as soon as possible. Therefore the system should be build so that it is easy to locate and solve problems when they occur. Weaknesses and bottlenecks should be mapped and alternative recovery plans need to be done in order to increase the reliability and robustness of the system. This mapping calls for skills in finding solutions to various potential technical problems.

However, a longer time perspective is important in development. Business thinking, architecture planning, vendor development and contract monitoring have

their emphasis on long-term positioning. The same long-term interest can be seen in developing business processes that support strategic goals, or planning technical architecture that is open and flexible in the future.

#### *4.5. Interplay of different types of skills and expertise*

The role of different skills and knowledge is empirically studied in interviews in six organizations. We interviewed top managers and IT managers in organizations from different industries in order to understand of the interplay of different skills and expertise in various stages of development of e-business infrastructure. As noted above, there are three types of skills and expertise – technical, business and interpersonal - needed in IT development. These skills and expertise are interdependent, even though they are different [20]. For example, people with a business background consider IT people competent not only on the basis of their technical expertise but they are also judged based on their business understanding and interpersonal skills. On the other hand, systems development is more successful if business people understand how technology can be applied. Here interaction with IT people and finding a “common language” are the key to success. Continuous discussion is also needed with other persons involved in the development work. This helps other stakeholders in understanding their role as in the puzzle one interviewed manager told.

Interaction is a critical element in information technology development [20]: the more there is discussion and cooperation, the stronger the mutual understanding will become. Here interpersonal skills are in a key role.

Even though technical expertise and business understanding are needed, discussion and interaction are needed to develop mutual understanding of the development goals.

The results of mutual understanding will materialize in better planning of new systems and more sophisticated use of existing information technology.

### 3. DEVELOPMENT OF THE E-COMMERCE INFRASTRUCTURE

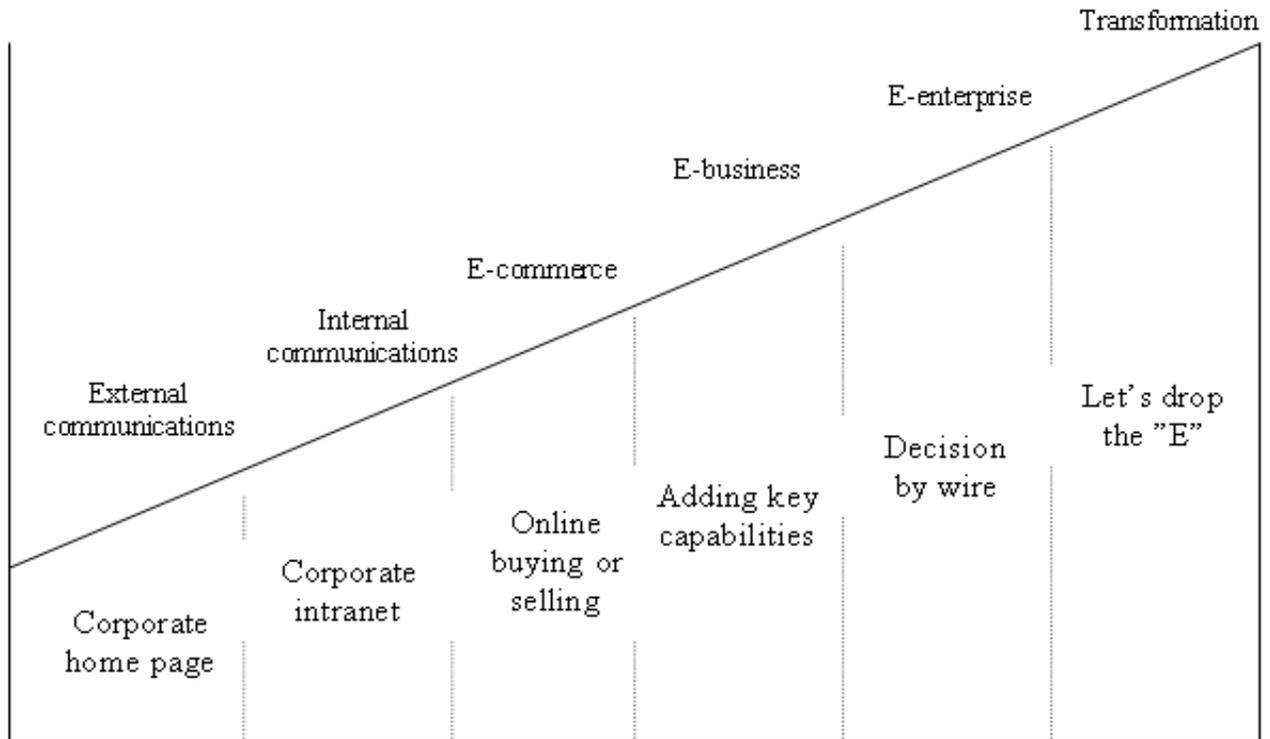
In general, information system development is defined as developing a system that meets needs or improving the existing system [21]. The development process involves organization of the process, mapping of the organization, mapping of the present state of information processing and the actual design process [22], [21]. Here we apply these stages into development of e-commerce infrastructure.

Once the need for moving towards e-commerce is identified the development process must be organized and a development group must be formed. Members of the group are often picked based on the skills, role and interest that

alternatives and make design choices. Also business understanding is vital as noted by interviewed business managers.

In development work can outside sources of information be valuable. These may include advice from consultants, academic people or experts. Also conferences, professional journals and other e-commerce sites can give ideas.

The second stage in the development work is mapping the organization. This refers to developing a mutual understanding of the key sectors of operations, how the information flows from one department and person to others etc. It is vital to have business understanding because e-commerce should be integrated to business processes. Obviously, business expertise and interactive skills are critical at this point.



**Figure 2: Evolving the e-enterprise (Earl, 2000)**

they have towards the e-commerce platform. Here business knowledge and interactive skills are at stake. A typical development group could include IT people, business managers and other key people, users and outside consultants. The important issue is that the development group has enough expertise in order to evaluate different

Mapping the present state of information systems refers to existing information system: the development group needs to understand what the underlying infrastructure is. For example, e-commerce applications are often linked to existing databases and financial systems. This is why new technology should fit into the

existing IT infrastructure [23], [10]. Building a robust and reliable system that integrates existing systems with new technologies is a challenge for the development group. Therefore the actual design process calls for technical expertise.

The development of an e-commerce infrastructure takes a long time. It involves also other than technical issues, for example identifying potential products and customers for e-commerce. Typically, the development of e-commerce is an evolutionary process of moving traditional business into e-business [24]. The other alternative is that company builds operations to Internet alone. In both cases there are several stages involved in the process (Figure 2). As Earl [25] notes "lessons learned in each stage and where each stage leaves behind critical imperatives for the next one".

In first two stages the main emphasis is often on external or internal communication. Possible applications range from company's home pages to extranets that connect business partners to company's information systems. In these stages learning how IT can be applied has an important role. It involves skills and knowledge in technology (web-technology, security etc.), business understanding (importance of up-to-date content on the home page etc.) and interactive skills (organizing the development work, involving technical experts, business people and outside service providers etc.).

The next two stages are about selling or buying online. The key challenges here are connected to promoting e-commerce, selecting and pricing products for e-commerce and managing brand. On a deeper level e-commerce and e-business involves positioning e-activities with traditional business and redesigning business processes [26]. These challenges require mostly business expertise and understanding of what are the strategic goals of e-commerce related activities in the company.

E-commerce makes it possible to collect and use data of all online transactions. It allows decision-making that is based on real-time information.

Therefore, management processes should be redesigned so up-to-date information can be used in company management. This can introduce new ideas of management control, thus being the basis for institutionalizing the online business model [24].

Another interesting framework of e-commerce positioning and development is a awareness/positioning framework (or commitment-implementation matrix) proposed by Stroud [27]. It is based on two questions: firstly, what is the managements' vision of the relative importance of technology. Secondly, how can Internet be integrated into existing organizational structures.

Based on these questions company's level of commitment ranges from wait and see –approach to business innovation where processes are redesigned so that the potential of Internet can be used maximally. Similarly, the mode of development varies from building separate applications to business centric development where the potential of Internet is understood [27].

The interplay of technical and business understanding is a key issue in this framework. If company lacks technical expertise, opportunities may be lost as technology is not utilized. It is also possible that the importance of technology is diminished, left to technical people alone and not considered worthy of management's time and effort [27], [28]. The solution to these problems is in interaction between technical people and less-technically oriented business people.

In general, interaction is recognized as one of the primary requirements for successful information systems development and implementation [29]. Open discussion and changing opinions are critical for the development work.

However, there are also other factors such as personal characteristics of the group members and rewarding methods that affect the interaction and performance of the development group. Consequently, enhancing group interaction and discussion are important, but may not automatically ensure better results.

#### 4. DISCUSSION

Development of e-commerce infrastructure – and information technology development in general - is more than making right technological choices. Managing the development process is a challenge, it requires business understanding in how technology can be utilized in the best possible way. The company's e-commerce platform and its role changes as the company integrates e-commerce into business processes [27], [25], [24]. Therefore e-commerce infrastructure involves continuous development.

The information technology infrastructure should be flexible so that it would be possible to modify it based on changes in environment and business needs. Despite this an organization's basic IT infrastructure is relatively stable over time [1]. Applications and information technology in business processes change more frequently because business processes need to be modified to meet customer needs, or as a response to changes in the competitive environment. For example, the e-commerce platform must be flexible in order to adapt to changes in business processes.

In general, technology is converted into IT infrastructure services through skills, knowledge and experience of people in the organization [8]. Ultimately, the value of information technology infrastructure depends on how effectively technical IT infrastructure can be converted into productive outputs [5]. The knowledge and skills of people who are developing new systems and services is considered as a critical success factor in information technology development [2], [15], [5]. Here we argue that technical, business and interactive skills and knowledge are important in information technology infrastructure development. Expertise from all three domains must be present in successful IT development activities. This is also the case in development of e-commerce infrastructure.

The relative importance of skills and knowledge varies depending on the development stage of the e-commerce platform. Interactive and business skills are

critical in the first steps of the development process when the project group is about to be formulated and the group members develop a mutual understanding of the development goals. Technical expertise is needed when different technologies are evaluated and the infrastructure is being planned. However, in later stages operations may increasingly rely on Internet, and company's whole business is built around e-commerce. Consequently, the importance of business understanding will increase when a company gets more committed to e-commerce [27], [25].

Ultimately, information technology needs to support organizational goals and therefore the role of ecommerce must be discussed. Discussions are important for understanding the potential of e-commerce and information technology in the company. Open discussion and interaction are the basis for development of a flexible e-commerce infrastructure that serves business goals.

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# Biometric Features for Mobile Agents Ownership

Salvatore Vitabile, Giovanni Pilato, Vincenzo Conti, Giuseppe Gioè, and Filippo Sorbello

**Abstract — Multi-Agent System (MAS) architectures can be used for e-Business application due their flexibility, scalability and interoperability. Agent ownership implies that a specific person or organization (the owner) is responsible for the agent's actions. Agents, whose ownership was certainly fixed, could operate on behalf of their owner to make transactions, to buy or sell products. Security requirements in the agent ownership setting process are the identification of the owner and the protection of the identification information carried by an agent. In this paper, we investigate the possibility of using biometrics in mobile agent systems for owner authentication. Biometric features can be used in both agents ownership setting process and in the protection of the agents information. Certification Authorities could also check against the owner reputation level before grant or deny permission of performing certain actions. In order to show the feasibility of the approach, the proposed techniques have been implemented and tested as an extension of the JADE-S platform.**

**Index Terms — agent ownership; biometric authentication systems, multi-agent systems security.**

## 1. INTRODUCTION

An e-Business agent community is a self-organized virtual space consisting of a large number of agents and their dynamic environment. Within a community, highly relevant agents group together

offering special e-Services for a more effective, mutually beneficial, and more opportune e-Business. Each agent community consists of agents specializing in a single domain/sub-domain, or highly intersecting domains. Agent Service Providers (AGSP) could provide a network infrastructure with strong network servers and local workstations to allow people use agent-services provided by them.

A mobile agent can be owned by individuals or organizations. An agent owner can use his/her agent to carry out tasks to fulfill its own purposes. Owners can offer agent services to individuals or organizations that are not in a position to own an agent.

Agent ownership implies that a specific person or organization (the owner) is responsible for the agent's actions. Yip and Cunningham raise several issues regarding software agent ownership, such as the related legal hurdles because existing law does not support the ownership of an active software instance [3]. In a framework supporting agent ownership, agents could be legal entities employed to bring their own principal into contractual relations with third parties. The authentication process establishes the identity of each owner and, consequently, of each agent. A policy, based on the previous identity, can determine the access level of an agent in e-Business systems, the permission to access to certain resources or perform certain tasks. The Agentcities Security Working Group has defined a set of security requirements identified for multiple agent platforms active in open distributed multi-domain networks. Among the application driven requirements, user authentication based on both invasive and non-invasive biometric features is suggested [1].

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Security requirements in the agent ownership setting process are the identification of the owner and the protection of the identity information carried by an agent. The first issue deals with the user authentication process while the second issue deals with information encryption techniques and certificates.

High security authentication system design still remains an open problem. Complex passwords are easy to forget while simple password are easily guessed by unauthorized persons. An unauthorized person, by stealing a trusted username/password pair, can gain access into a system and run malicious agents to perform unauthorized transactions. The original owner will be the legal responsible of these actions.

In a mobile-agent framework, biometric based authentication systems can be used to improve the owner authentication process security. So, it is possible to authenticate an individual's identity based on "who the user is", rather than by "what the user has" (e.g., an ID card) or "what the user remembers" (e.g., a password) [7], [26]. As a consequence, agent and owner reputations are strictly related and they can be considered as a single entity. A network authority can temporarily or permanently suspend or revoke digital certificates to untrusted agents (users).

In this paper, the mobile agent ownership issue is addressed by introducing biometric based systems in the user (owner) authentication process.

Biometric features are conveniently divided into two main categories. The physiological features include face, eye (normally, retinal or iris patterns), fingerprints, palm topology, hand geometry, wrist veins and thermal images [29],[30]. The behavioral features include voiceprints, handwritten signatures and keystroke dynamics. In general, physiological features have been more successful than behavioral features to implement authentication systems of such characteristics. This is not difficult to understand: physiological features essentially do not vary with time, whereas behavioral features such as signature and keystroke dynamics may change greatly

even between two consecutive samplings [29],[30].

A biometric based authentication process is based on two sequential phases. In the enrolment phase, the system acquires individual biometric information like a kind of registration template. In the matching phase, the currently acquired biometric information is compared with that stored in order to determine whether or not they belong to the same person.

A fingerprint based authentication system for the JADE-S platform has been proposed by the authors in [2]. JADE-S is a FIPA (Foundation of Physical Intelligent Agents) compliant multi-agent platform supporting a username/password based user authentication process. JADE-S is formed by the combination of the standard version of JADE with the JADE security plug-in [10], [11].

In this paper, we will address the possibility of using biometrics in mobile agent systems starting from the above implementation. Biometric features improve the security in owner authentication, since an owner will be authenticated with his/her intrinsic bodily characteristic. A mobile agent proves its identity by showing its Identity Certificate, signed by a Certification Authority. Using digitally-signed certificates with biometric information, the platform can be sure of the agent owner identity. The Certification Authority could also check against the owner reputation level before granting or denying permission to perform certain actions.

The paper is organized as follows. In section 2 the implications of agent ownership on agents trust and reputation are briefly discussed. In section 3 a brief description of the common biometric features used for human authentication is reported. In section 4 the implementation of the proposed extensions in the JADE-S platform is outlined. Finally, in section 5 some considerations about owner privacy are reported.

## 2 .TRUST AND OWNER REPUTATION

The problem of trust has many implications in an open distributed environment. In e-business transactions, an agent needs to decide, when another agent

is encountered in the network, if that new agent can be trusted or not.

Many researchers treat ownership as a passive ingredient of trust. In [13] Jurca and Faltings proposed to link agent trust to the agent reputation, i.e. the collection of the agent related information about its past behavior. Rahman and Hailes [12] have proposed a distributed trust model based on the assumption that an agent will be able to keep a history of interaction with other agents and hence assign different level of trust to the peers. However, as pointed out in the scenarios, it is not always possible to obtain the necessary records to decide the level of trust towards an agent, especially when there is no direct relationship between the real world legal entity and the software agent representing it.

In the multi-agent system design phase, it is essential to provide individual agents with various forms of social awareness in order to support rich collaborative behavior [4], [5], [6]. Mamdani and Pitt [5] have suggested that an agent should be able to express the fact that an agent is owned by some human entity. Furthermore, the agent should be able to reason about the consequences and responsibilities of the delegation.

In agreement with Yip and Cunningham [3], secure user authentication helps to sustain a trust model including agent ownership. Here, we distinguish two different types of owner:

- The *authors* are people or organizations that write programs to execute an agent;
- The *senders* are people or other entities that send agents to act on their behalf.

In the mobile agent identification issue, X.509v3 digitally-signed certificates, containing owner biometric information, can be adopted. Certificates are useful for agent authentication as well as to carry information about Agent Owner Reputation (AOWR). AOWR can be included in digitally-signed certificates and used by platforms and agents to grant or deny permission to a mobile agent. A trusted multi-agent platform with agent execution tracing capabilities can decrease AOWR for authors and senders

whose agents are malicious or untrusted. An enabled Certification Authority (CA) can temporarily or permanently suspend or revoke digital certificates of untrusted agents/owners.

### 3. BIOMETRICS FOR AUTHENTICATION

Mobile agent ownership requires reliable personal recognition schemes to determine and confirm the identity of an agent. Common authentication systems for multi-agent platform are based on username and password. Three well-known user authentication systems are Kerberos, NetSP, and SPX [23], [24], [25].

Therefore, the above approaches are based on username and password with the use of cryptography techniques to protect data integrity from possible attacks. Using biometric features, we introduce a second security level in the user authentication process.

The following two procedures are generally used for identity verification with biometric features [14]:

- enrolment: the system acquires an individual biometric information building a template;
- matching: the acquired biometric information is compared with the stored individual biometric information to determine whether or not they belong to the same person.

Different biometric features can be used in the user identification process. Some of these features can be considered invasive biometrics (e.g. fingerprints, retina) and they may not be desirable as they infringe on privacy, others that are not unique or robust (e.g. hand geometry, voice) are less invasive. User authentication systems can be divided into verification and identification systems. A verification system performs the comparison 1->1 between the sensor acquired biometric features and the single related stored item. An identification system performs a comparison 1-> many between the sensor acquired biometric features and many stored items in order to individualize user identity within a group of enrolled users.

The most important parameters to evaluate a biometric based authentication system are the Genuine Acceptance Rate (GAR) and the False Acceptance Rate (FAR). False accept errors are very dangerous for an authentication system, so FAR value is very restrictive. FAR common values range from  $10^{-2}$  (basic security applications) to  $10^{-6}$  (high security applications).

In what follows, a brief description of four primary methods of biometric authentication are reported.

#### A. *Voice recognition.*

The authentication process is based on some major characteristics such as cadence, frequency, pitch and tone of an individual's voice. Common implementation of voice based authentication systems give, as best result, the 90% of classification rate [18], [20]. As a consequence, a simple voice based verification system can be used for applications where a high security level is not required. Voice can be used in multi-biometric systems [18].

#### B. *Face recognition.*

Face recognition is a non-intrusive method that has advanced considerably in the last decades. The most common approaches to face recognition are: a) the location and shape of facial attributes, b) the global analysis of the face image that represents a face as a weighted composition of a set of canonical faces. A face recognition system needs a generic camera for face images, a very simple recording phase. Furthermore, the matching process is based on a high number of features. In the last competition, FRVT2002, the best obtained results was the 90.3% of recognition percentage with a FAR of 1% and the 71.5% of recognition percentage with a FAR of 0.01%. Experimental trial was performed on a database of 37.437 individuals [16], [17].

#### C. *Iris recognition.*

The iris is the annular region of the eye bounded by the pupil and the sclera on either side [28]. Each iris is distinctive and, like fingerprints, even the irises of identical

twins are different. Iris recognition systems require special iris cameras with very high resolution and infrared illumination abilities. Using standard CASIA Iris database, different methods have been developed for iris based authentication systems. The obtained results range from 92.64% (Boles et al. [19]) to 100% (Daugman [22]).

#### D. *Fingerprints recognition.*

Fingerprints have been used for personal identification since the 1880s, and the matching accuracy using them has been shown to be very high [7], [8]. Everyone is presumed to have unique, immutable fingerprints [27]. However, the probability that a fingerprint with 36 minutiae points will share 12 minutiae points with another arbitrarily chosen fingerprint with 36 minutiae points is  $6.10 \times 10^{-8}$  [21]. These probability estimates show that fingerprint matching is not infallible and leads to some false associations. Today, the implementation of a fingerprints based authentication system is very simple and inexpensive and shows interesting results. A good system reaches the 99.4% of recognitions percentage with a FAR of 0.01% and the 99.9% with a FAR of 1% [17].

### 4. CASE STUDIED: THE JADE-S PLATFORM

In this section our experience using a multi-agent platform with a biometric based authentication system is described. Starting from the biometric agent owner setting, x.509v3 digital certificates for agent authentication and certification have been personalized and used.

As framework we have chosen the JADE-S platform, a FIPA (Foundation of Physical Intelligent Agents) compliant multi-agent platform. JADE-S is formed by the combination of the standard version of JADE with the JADE security plug-in [10], [11]. JADE-S platform supports some security issues such as authentication, authorization, permissions and policies, certificates and certification authority. However, neither is biometric authentication module provided nor digital certificates with extended information managed.

Several types of biometric authentication systems could be used for user authentication. A fingerprint based authentication system for the JADE-S platform has been proposed by the authors in [2]. The whole platform as well as each single agent can be activated only by authenticated users. The activated agent will own a digitally-signed X.509v3 certificate containing owner personal information, owner authentication information (matching function and matching score) and the owner reputation rating.

Our solution is based on a set of PKI techniques including certification authorities, private/public keys, and digitally-signed certificates. With more details, the multi-agent platform has been extended implementing a new Login Module (LM) and an enhanced Security Certification Authority (SCA). The LM is able to deal with username, password and fingerprint. The SCA is able to deal with digitally-signed X.509v3 certificates. In what follows, the description of both JADE-S platform and developed modules (LM and SCA) are given.

#### A. The JADE-S platform

The Foundation for Intelligent Physical Agents (FIPA) developed specifications for the implementation of multi-agent systems. The physical infrastructure in which agents can be deployed consists of: the hardware platforms, the operating system, the agent support software, the FIPA agent management components: the Directory Facilitator (DF), the Agent Management System (AMS), the Agent Communication Channel (ACC), and the Internal Platform Message Transport.

According to the FIPA specifications, there must be at least one DF agent per platform. An agent can register its services in the DF. The DF allows *Yellow Pages* services and the agent can submit a query to the DF in order to find the required service. Furthermore, the DF maintains an accurate, complete, and up-to-date list of agents. The AMS is unique to the platform and is responsible for managing the agent creation, deletion and migration. The ACC routes messages between agents within the agent

platform to agents resident on other agent platforms.

JADE (Java Agent DEvelopment framework) is a FIPA compliant software framework fully implemented in Java language which simplifies the implementation of multi-agent systems. The platform can be seen as a middleware providing a set of useful tools that support the debugging and deployment phase[11].

JADE-S is formed by the combination of the standard version of JADE with the JADE security plug-in [10], [11]. JADE-S includes security features such as user/agent authentication, authorization and secure communication between agents into the same platform. With more details:

- Authentication: a user must be authenticated by providing a username and password, to be able to own or perform actions on a component of the platform. Only authenticated users can own AMS, DF, containers and other agents;
- Authorization: JADE-S uses the concept of Principal as an abstraction for a user account, an agent or a container. A Principal must be authorized by the Java security manager. The security manager allows or denies the action according to the JADE platform's policy;
- Permissions and Policies: a permission is an object that describes the possibility of performing an action on a certain resource such as a piece of code, but also executes that code. A policy specifies which permissions are available for various principals;
- Certificates and Certification Authority: the Certification Authority (CA) is the entity that signs all the certificates for the whole platform, using a public/private key pair.
- Delegation: this mechanism allows the "lending" of permissions to an agent. Besides the identity certificate, an agent can also own other certificates given to it by other agents;
- Secure Communication: communication between agents on different containers/hosts, are performed using the Secure Socket Layer (SSL) protocol. This enables a solid protection against malicious attempts of packet sniffing.

## B. The Developed Extensions

### B1. The Login Module

The Java Authentication and Authorization Service (JAAS) [9] allows:

- user authentication, to reliably and securely determine the user which is currently executing Java code;
- user authorization, to ensure they have the access control rights (permissions) required for the requested actions.

According to the three paradigms illustrated in the previous section (i.e. what the user knows, what the user has, what the user is), JAAS has been configured to deal with agent code and agent owner authentication.

The developed Login Module manages the platform access system dealing with:

- a. owner username and password;
- b. a stored key containing owner credential;
- c. owner fingerprint information.

The Login Module is depicted in Fig. 1; the module is composed by the following blocks:

- *JAAS LoginContext*: it is responsible for the authentication process. It reads a configuration file, named “jaas.config” and starts the appropriate LoginModule.
- *JAAS LoginModule*: it creates a callback handler to acquire the user’s credentials. The credentials are sent to the E-CSAI Authentication Service that verifies them. If the verification is positive, the object session is generated.
- *E-CSAI Authentication*: it verifies the user’s credentials and returns “true” or “false”. It checks also the username with the associated password, verifies the certificate authenticity, and performs the fingerprint matching.
- *Session object*: it contains a Principal Entity which is an authenticated entity having shared state for trusted multi-platform migration; a Public Credential (a public key); and a Private Credential (a private key).

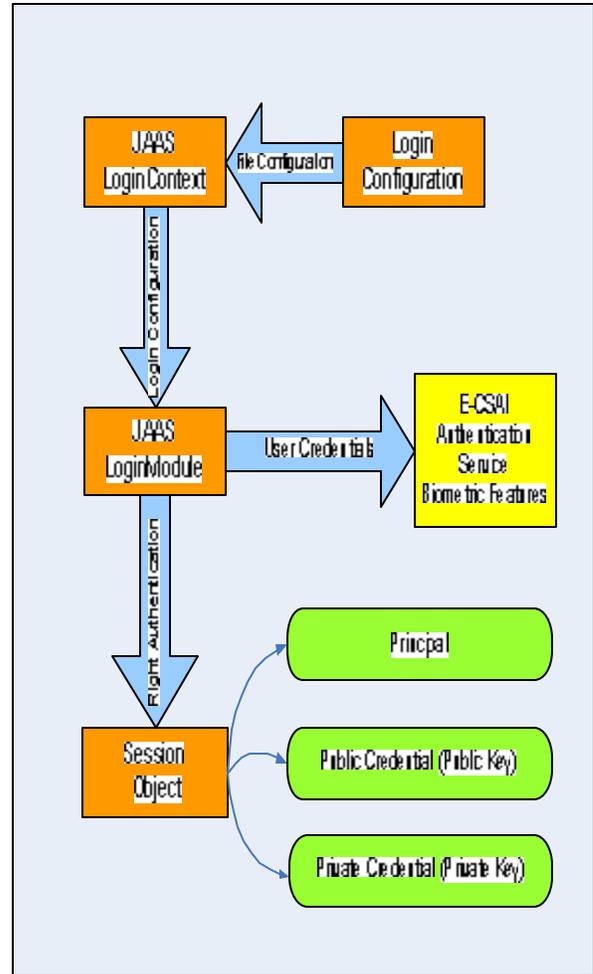


Figure 1. The Login Module and its components.

Authentication system procedure is the following:

1. *username and password request*;
2. *user data verification*;
3. *if the user is not registered (enrolment phase)*
  - 3.1 *a Registration Module starts requiring user personal data*;
  - 3.2 *user personal data acquisition*;
  - 3.3 *user fingerprint acquisition*;
  - 3.4 *X.509v3 certificate and signed biometric information releasing*;
4. *if the user is registered (matching phase)*:
  - 4.1 *signed biometrics data and certificate requests*;
  - 4.2 *owner fingerprint acquisition*;
  - 4.3 *fingerprint matching*.

The triplet (*username, password, fingerprint*) is adopted in order to have three different *authentication items and to prevent Denial of Service (DoS) attacks* for the fingerprint verification process.

**B2. The Security Certification Authority**

Agent communications are managed with an extended version of the X-Security 2.0 package [15]. X-Security 2.0 supplies a secure model for inter-platform communication, opening several secure communication channels at the same time also with untrusted networks (differently from SSL).

X-Security 2.0 package has the following basic functionalities:

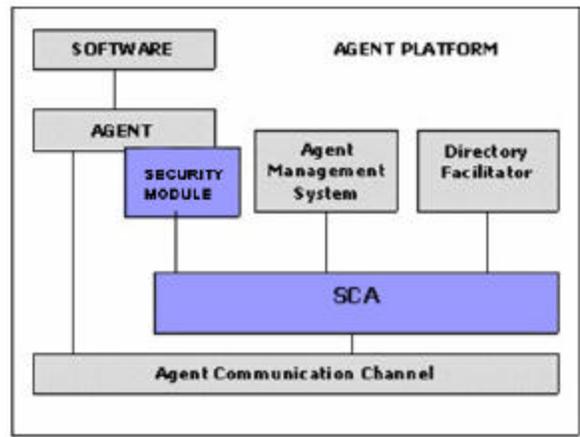
- a Security Certification Authority (SCA)
  - SCA is an independent agent which can temporarily or permanently suspend, renew or revoke agents digital certificates. It is not a part of the platform (like AMS or DF);
- a Security Module (SM) – SM is an optional module that each agent adopts for secure communications. If no secure communications are required, the agent use the standard Agent Communication Channel.

The SCA has been extended adding the described Login Module (based on fingerprint), a Registration Module (for the enrolment phase), and a Certificates and Keys Manager for X.509v3 certificates.

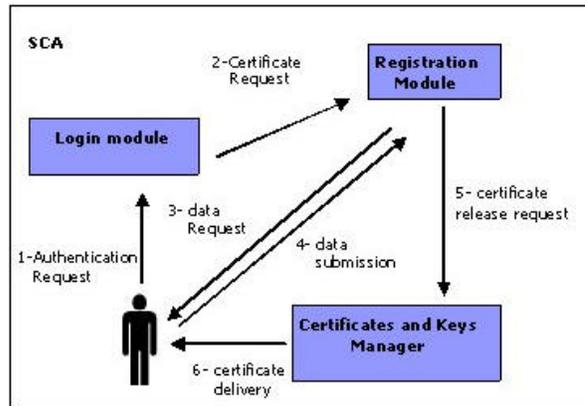
The Extensions field of the X.509v3 certificate contains:

- the name of the function to use in the matching phase. The function must be shared by the SCA;
- the minimum score needed for a positive match;
- the owner reputation rating.

The developed SCA is able to deal with the above items implementing the related policies to grant or deny permission for performing certain actions. A mobile agent proves its identity to the platform by showing its Identity Certificate, signed by a SCA. The Certification Authority also checks against the owner reputation level before to grant the possibility of performing an action or accessing to a resource.



**Figure 2.** Agent platform structure with the emphasized SCA and Security Module.



**Figure 3.** The extended SCA with the Login Module, the Registration Module, and the Certificates and Keys Manager for X.509v3 certificates.

In Fig. 2, the agent platform structure with the emphasized SCA and Security Module is depicted. In Fig. 3, the new extended SCA with the Login Module, the Registration Module, and the Certificates and Keys Manager is depicted. In the figure the sequential steps of the enrolment with the final certificate delivery step is also reported.

**C. Experimental Results**

It is well known that attempts to compare biometric error rates with password and token security have had only a limited degree of success because the factors that

influence security are substantially different for biometrics than for traditional authentication mechanisms.

We have developed a new multi-agent platform with the characteristics illustrated in the previous sections in order to test the feasibility of the proposed approach. We have made use of 56 people, usually attending our laboratory, to test the authentication system easy-of-use. It is worthwhile to point out that 2 people refused to give us their fingerprints, while the remaining 54 people were willing to contribute. Experimental trials, conducted with 54 fingerprint pairs, show the feasibility of the system, which attained a 100% rate of success.

## 5. CONCLUSIONS

Strong owner agent authentication implies interesting discussions about the existing trust models developed for intelligent agents. Agent and owner reputation can be considered as a single entity and a network authority can temporarily or permanently suspend or revoke digital certificates to untrusted agents (users).

Some biometric methods can be considered invasive (e.g. fingerprints, retina) and may not be desirable as infringing on privacy. To protect the privacy of the persons involved, it is important that these personal data are used with care. They must be used if and only if they are necessary for legitimate purposes. Personal data will not be disclosed to the wrong persons and they will not be processed without the knowledge of the persons concerned. A Security Certification Authority holds these issues in high regard. Therefore, the use of agents and the processing of personal data have to meet certain conditions. These conditions derive from the principles of privacy which are laid down in many laws and international treaties.

The use of biometric characteristics for ownership determination, will allow an increased level of security for all those applications, like e-commerce, e-banking, and so on, for which the determination of agent ownership is crucial.

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# Using Technology to Conduct Research in Education

Dianne A. Wright

**Abstract—Technology has changed the way research is conducted by academicians in all disciplines. Unfortunately, however, the availability of research on this topic in the field of education, where one is more likely to find instructional technology as the focus of related research studies, is a problem. The author recommends solutions to this problem including not only an increased focus on the availability of such technologies, but also the extent to which these technologies are used by educators as well as their perspectives regarding concomitant advantages and disadvantages. The fact that such technologies are coming into existence as fast as they can be documented, while but one limitation noted, is more reason for comparative analyses that can be used to inform next generation technologies.**

**Index Terms— Internet, World Wide Web, research, educational policy analysis.**

## 1. INTRODUCTION

THE Internet or World Wide Web (www) emerged in the 1990s as an important new source of mediated messaging (Neuendorf, 2002). Subsequently, research and scholarship in higher education has changed. Interestingly, however, very little has been written on this topic by academics in Education. In fact, no related research studies can be found in the literature. The latter is particularly significant in comparison to the volumes that have been written related to this topic in other disciplines and the amount of research that is reported in Education in the area of instructional

technology. Traditional research methods involve extensive photocopying of paper-based journals and books and note-taking. Today's twenty-first century research methods demand the use and knowledge of the Internet to access indices and abstracts (e.g., [formerly] ERIC, Psychological abstracts, etc.). Further, the World Wide Web has the capacity to combine characteristics of existing media (e.g., print, audio, and video) with a number of new critical attributes including hypertextuality and interactivity (Newhagen & Rafaeli, 1996). In addition, electronic or online survey system software packages are now available – offering sophisticated questionnaire logic features.

It is now increasingly common for a faculty member to use remote data bases, exchange e-mail globally, collaborate on research, and get copies of the latest journals all online. The “new scholar” on the internet uses distant libraries, meets new colleagues online, and exchanges ideas and knowledge in real time with academics around the world. No longer are they bound to traditional hard copy journals and books.

The extent to which scholars in Education are using the full array of available technology resources to conduct academic research, however, begs for empirical perspectives, not to mention perceived advantages and disadvantages or effectiveness of these transforming technologies. The purpose of this article is to begin to address this gap.

## 2. TECHNOLOGY UTILIZATION

Utilization of the Internet and related technologies to conduct academic research can be organized into three broad

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categories: (1) information and data collection, (2) data, statistical, and text analysis, and (3) results communication.

#### *Information and Data Collection*

Electronic mail (e-mail) is the most wide spread internet/technology service used by all academics. In addition to its obvious use for sending and receiving messages, e-mail has become the basis for what are many other academic research related activities. There are, for example, discipline specific discussion groups that use automated systems to transmit and receive e-mail messages from one person and then automatically to everyone else on a designated list. E-mail can also be used to get files from file transfer protocol (FTP) sites, find resources through various search engines, and get information from databases (Ellsworth, 1997, p. 506).

In addition, several electronic (online) journals have come into existence over the last decade. Academics serve as editors and referees for these online journals, and receive and critique articles using e-mail. Also, opportunities for collaboration in developing thematic journals and writing articles at a distance has become increasing common and many paper-based journals now allow electronic submission of text using the Internet (Ellsworth, 1997, p. 414). On-line surveys can also be conducted using e-mail or web survey software for purposes of information and data collection. E-mail surveys involve sending a survey to a list of individuals who then reply with their answers. Web-based surveys involve posting a questionnaire on a web page that potential respondents visit.

These software systems are interactive. They present and gather information from respondents through standard web browsers and store the data in e.g., an Oracle ® or Microsoft® SSQL Server™ database. Examples include the 2WAY survey system currently being piloted at the University of Akron in Akron, Ohio and Perseus being piloted at Florida Atlantic University in Boca Raton, Florida.

2Way is a JavaScript™ application embedded in an HTML document, deployed

to the Internet via a web server. 2WAYs intelligently gather feedback through multiple user-defined logic paths. Using this logic, a 2WAY interaction responds to user feedback with new questions and elements based on their responses, helping to tailor content to individual recipients (<http://www.2way.com/products/is/what.htm>).

Perseus, represents yet another web-based survey software system available to academic researchers. The survey processor can run on any server operating system (OS), enabling each organizational unit to use the server OS that best fits its needs (e.g., Perl, Java, Python.net). Survey results can be managed in Oracle, SQL, server, Sybase, or DB2, enabling institutions and faculty to use their current database standard (<http://www.perseus.com>).

#### *Data, Statistical, and Text Analysis*

Most web-based survey systems can also be used to analyze research data. Respondent data can be formatted to contain bar charts, pie charts, and itemized lists of text responses representing both aggregate and individually collected data (<http://www.2way.com/products/is/what.htm>, [http://www.perseus.com/survey/news/release\\_efm\\_trade.html](http://www.perseus.com/survey/news/release_efm_trade.html); <http://www.surveysystem.com/websurveys.htm>).

Most academic researchers are very familiar with electronic versions of SPSS and SAS, particularly in Education. In addition to the typical SPSS and SAS software programs, SIMSTAT for Windows: Simulation and Statistics, v2.5 might also be considered. SIMSTAT is a statistics program that provides for the conducting of a wide range of statistical analyses of a descriptive nature including cross-tabs, t-tests, ANOVA/ANCOVA correlations, linear, nonlinear and multiple regression analyses, time-series, and reliability, etc. SIMSTAT, however, goes beyond mere statistical analysis. It offers output management features as well as its own scripting language to augment statistical analysis and write small applications, interactive tutorials with multimedia capabilities, and computer assisted interviewing systems. (<http://www.exetersoftware.com/cat/simstat>).

<http://www.simstat.com/simw.htm> ) The 2Way Survey Interactive System as well as Perseus, mentioned earlier, also provide for automated statistical analysis. In addition to web-based questionnaires, Perseus allows for telephone-based interviews with sound and graphic images, and has a report "indexer" (an add-on function) that can be used for purposes of benchmarking. No where in the literature, however, did the researcher find any studies of the extent to which these various technology resources are actually being used by faculty researchers in education.

In addition, quantitative computer text analysis software is available. As early as 1997, Skalski (p. 225) provided a listing of quantitative text analysis programs and highlighted key features of each. Most of these software programs as identified by Skalski (1997) were able to perform quantitative and or qualitative text analysis functions such as the development of alphabetical lists, frequency lists, multi-unit data file output in (case-by-case) variable form, key word in context (KWIC) or concordance, coding with a built in (standard) dictionary, and coding with a user-created (custom) dictionary as well as other special analyses.

After WWII, the development of the digital computer sparked widespread interest particularly in formal, quantitative computerized models to convert "soft" problems into "hard" ones. Subsequently, a new breed of technical practitioners came into being, including policy researchers who began to use formal computerized modeling techniques to address economic, business, and social policy in addition to e.g., differential and inferential statistics.

As noted by Gill and Sanders (1992), statistical methodologies such as multiple correlation, log-linear modeling, and analysis of variance can provide valuable insights into relationships among variables in the policy environment. Such work has come to be more specifically referred to by educational policy researchers as "policy analysis." A listing of related differential technologies available to and/or used by the education policy analyst also remain, however, conspicuously absent in the

education literature. Empirical evidence of how these differential technologies have impacted the work the education policy analyst, also remains unknown.

### *Communicating Research Results*

E-mail and Web-based surveys such as 2Way and Perseus Interactive systems allow for respondent data to be published as HTML reports, research articles, or be exported to third-party analytic tools for purposes of report writing and preparing for dissemination. Using these technologies, resulting reports and research articles can also be formatted to contain bar charts, pie charts, and itemized lists of text responses representing both aggregate and individual views of collected data. It is also noted that it is becoming more commonplace for such reports and research articles to be published online in electronic journals.

In terms of citing references, *End Notes* represents one of many software packages available for citing references once research findings are written and prepared for publication. Again, however, no empirical research has been published that describes the extent to which education researchers use or do not use this or similar software. Empirical evidence in terms of advantages and disadvantages, along with recommendations identifying more contemporary product software could prove invaluable to the educational researcher.

### *Limits To Using Technology to Conduct Academic Research in Education*

There are limits, however, in terms of using technology to conduct academic research in Education. One limitation is costs. Technology infrastructure continues to need more funds. Colleges of Education are being required to spend huge amounts of their budgets on computer-related support. A second limitation is time for training and education. In addition to Education faculty typically carrying greater teaching loads than faculty in the so called "hard" disciplines, they are also held to traditional research and service

requirements. And, third though not final in terms of limitations - one drawback noted by Lindblom (1992) is that it is still impossible to take all factors into consideration in data collection and analyses. No matter how sophisticated the technology, all possible outcomes can not be projected. As such, resulting policy changes in Education tends to be incremental. As new analyses are conducted or new, more sophisticated technologies emerge, the policy will continue to change, infinitum. This latter would also be the case with traditional paper and pencil approaches as well. The advantage of technology would lie in a quicker turn around time of analyses that can be used for purposes of research reporting.

### 3. SUMMARY/CONCLUSION

Empirical research is needed to determine the extent to which academicians in education researchers are using technology to conduct their research. The results of such research would provide useful insights not only into the various technologies that have emerged more recently and are being used to conduct research, but also the applications, strengths, and weaknesses of each. Short of this much needed empirical data, a well organized web site listing such applications as they emerge, inclusive of links and tutorials, would be a good starting point. Future research could include topics such as how technology is continuing to change the way academic research is conducted, perceived advantages and disadvantages of emerging research techniques and related effectiveness and efficiency studies.

Today, education needs professionals more capable than ever in terms of analyses and management of complex problems, and knowledge production. Technology can help, but these professionals - many who are education researchers - must have or create empirically-based insights in terms of what technologies are available, including empirically proven strengths, weaknesses, and potentialities.

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January 5 to 8, 2006

### **IPSI-2006 AMALFI**

Hotel Santa Caterina  
Amalfi, Italy  
February 16 to 19, 2006

### **IPSI-2006 AMSTERDAM**

Amsterdam, Holand  
March 10 to 12, 2006

### **IPSI-2006 PARIS**

Paris, France  
April 22 to 25, 2006

### **IPSI-2006 MARBELLA**

Marbella, Spain  
May, 2006

### **IPSI-2006 BELGRADE**

Belgrade, Serbia  
June 1 to 4, 2006  
With Visits to  
Famous Serbian Monasteries

### **IPSI-2006 USA**

Hotel@MIT, Cambridge  
Massachusetts, USA  
July 6 to 9, 2006

### **IPSI-2006 PESCARA**

Hotel Castello Chiola  
Loreto Aprutino, Italy  
July 29 to Aug 5, 2006

### **IPSI-2006 STOCKHOLM**

Grand Hotel  
Stockholm, Sweden  
September 23, 2006

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